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Case Study of the Four-Year Neuropsychological Changes in an Elderly Male with Possible Chronic Traumatic Encephalopathy

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CASE STUDY OF THE FOUR-YEAR NEUROPSYCHOLOGICAL CHANGES IN AN ELDERLY MALE WITH POSSIBLE CHRONIC TRAUMATIC ENCEPHALOPATHY

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ABSTRACT

CASE STUDY OF THE FOUR YEAR NEUROPSYCHOLOGICAL CHANGES IN AN ELDERLY MALE WITH POSSIBLE CHRONIC TRAUMATIC ENCEPHALOPATHY

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Research demonstrates that the brain's response to Traumatic Brain Injury (TBI) is variable with age and the effects of TBI on the elderly are a critical and global public health concern, from both a medical and a neuropsychological perspective. Currently, there is scant research on the effects of TBI, including Chronic Traumatic Encephalopathy (CTE), on the elderly. Specifically, there is a paucity of literature regarding longitudinal neuropsychological changes in elderly post-TBI individuals. This dissertation will present a Single Case Research Design (SCRD) analysis of an elderly individual with possible Chronic Traumatic Encephalopathy and the associated neuropsychological changes over 49-months. This dissertation is available in open access at AURA, http://aura.antioch.edu/ and Ohio Link ETD Center, https://etd.ohiolink.edu/etd.

Keywords: case study, geriatric, traumatic brain injury, chronic traumatic encephalopathy, neuropsychological evaluation

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Introduction

Elderly individuals face many unique challenges due to their age and corresponding, albeit variable, health conditions (Foster, 2016; Gaebel & Keiser, 2017). Traumatic Brain Injury (TBI) is one such health condition that, as will be discussed, is particularly pressing. And yet, TBI's effects on geriatric patients are insufficiently discussed in academic and professional bodies of literature. Using a single case research design, this dissertation analyzes the longitudinal sequelae of an elderly individual who incurred subclinical brain trauma. It will highlight the need for future neuropsychological research to address the needs of the burgeoning geriatric population.

Generally, the research on geriatric traumatic brain injury suggests that the brain's response to Traumatic Brain Injury (TBI) "is not uniform across the lifespan" (Gordon, 2013, p. 197). However, as this dissertation's literature review will show, there is little research on the effects of TBI on the elderly, and the literature regarding longitudinal neuropsychological changes in post-TBI elderly individuals is virtually non-existent. With a rapidly increasing geriatric population in the 21st century, the effects of TBI on the elderly are a critical global public health concern. As such, the objective of this dissertation is to broaden the understanding of the social and economic effects of TBI in the elderly.

Moreover, research regarding the effects of TBI in the elderly has predominantly been conducted through the lens of clinical medicine, with relatively few scholarly studies published by neuropsychologists. Given the paucity of neuropsychological literature regarding post-TBI longitudinal neuropsychological changes in the elderly, the literature review will paint a picture of TBI's unique impact on elderly populations through an examination of relevant co-occurring issues. The paper will then analyze a case study of an elderly individual involved in a motor

vehicular collision and the neuropsychological changes observed through multiple neuropsychological assessments spanning 49 months. The case data will illustrate unique aspects of TBI sequelae progression as well as posit the critical need for further research and evaluation.

Geriatric Demographics in the United States

In the United States and globally, life expectancy is increasing (Arias, Curtin, Wei, & Anderson, 2008) and mortality rates are decreasing (Hoyert, 2012), leading to a growing population of individuals aged 65 years or older. In the United States, this elderly population constitutes approximately 40 million individuals or 13% of the population. By 2030, it is expected that 20% of the population in the United States (72 million individuals) will be age 65 or older (Federal Interagency Forum on Aging-Related Statistics, 2012). As the elderly population grows, the number of elderly people affected by TBIs rises proportionally. Increases in incidences of TBI creates significant social and financial burdens, such as higher costs for healthcare and supportive care. Perhaps more significantly, TBI in the elderly can have serious impacts on functioning and quality of life if neurorehabilitation is not instituted (Gardner, Dams-O'Connor, Morrissey, & Manley, 2017).

Epidemiology: Traumatic Brain Injury—US and Worldwide Prevalence

Traumatic brain injury can be devastating at any age, for both the individual and their family and friends. In the United States, there are an estimated 1.7 million TBIs annually. Further, it is estimated that TBIs are a contributing factor in 30.5% of all injury-related deaths, with individuals age 75 years and older incurring the highest rates of TBI-related hospitalization and mortality (Faul, Xu, Wald, &, Coronado, 2010). Other statistics indicate that TBIs account for 2.4 million emergency department visits per year in the United States.

Similar rates of increase are found in other countries around the world. In the European Union (EU), TBIs account for approximately one million hospital admissions each year (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusingye, 2007). International epidemiological investigations in first world nations such as the Netherlands, Finland, and Australia provide corroborating evidence for the notion of increasing rates of geriatric TBI related to associated trauma such as falls. In the Netherlands, from 1986 to 2008, there was a rise in rates of hospitalization of the elderly who incurred a fall (Hartholt et al., 2011). In Finland, between 1970 and 2011, a 40-year follow-up study documented an age-adjusted incidence increase of 289% for females and 315% for males aged 80 years or older who sustained fall-related TBIs (Korhonen, Niemi, Parkkari, Sievänen, & Kannus, 2013). Finally, in Australia, hospitalization rates for geriatric TBI increased from 19.3/100,000 to 72.2/100,000 for the years 1998 to 2011;males were found to consistently incur higher hospitalization rates (Harvey & Close, 2012). The increased incidence of TBIs in a growing elderly population is then a global issue, not only for industrialized countries but for states at all stages of economic development.

Epidemiology of Geriatric Injury and Mortality in the United States

In the United States, data from the Centers for Disease Control's National Center for Injury Prevention and Control indicate that unintentional falls caused the death of 21,650 elderly individuals in 2010, compared to 6,040 deaths attributable to Motor Vehicle Collisions (MVC; Centers for Disease Control and Prevention, 2013a). Four years earlier, falls (51%), distantly followed by motor vehicular collisions (9%), were the leading cause of TBIs in the elderly (Thompson, McCormick, & Kagan, 2006). This data does not, however, account for the vast and unknown number of unreported and undiagnosed TBIs whose residual symptoms may manifest as effective or cognitive disturbances.

Increased Vulnerability in the Geriatric Population

Research shows that injurious falls in the geriatric population present a phenomenon in which the injury is disproportionate to mechanism; hence, the elderly individual is seven times more likely to die from the fall compared to a younger individual (Sterling, O'Connor, & Bonadies, 2001). Given the greater severity of TBI impact on elderly individuals, it is imperative to ask: What are the rates of falls in the elderly? In the Netherlands, a large cohort study of 1469 elderly community-dwelling individuals found that 30% of elderly individuals fell each year, with the incidence rate increasing with age (Tromp et al., 2001; Tromp, Smit, Deeg, Bouter, & Lips, 1998). A 2008 retrospective evaluation of medical records at a U.S medical facility found extensive pre-existing medical comorbidities across a range of cardiac, renal and body mass symptoms for 708 elderly fall patients, ages 75 years or older (Siracuse et al., 2012). In this population, the 30-day mortality rate was 6%, with 14% of the patients discharged being readmitted within an average of 12 days. In other words, not only were the rates of falls higher in older cohorts, but the severity of the sequelae was disproportionately greater, especially when exacerbated by pre-existing medical conditions such as renal failure (Abdel-Rahman, Turgut, Turkmen, & Balogun, 2011), hypertension (Sirkin & Rosner, 2009), or psychiatric comorbidities (Blair & Gruman, 2016; Greene et al., 2001). Thus, advanced age increases the likelihood that individuals will be taking multiple medications, which increases vulnerability to falls, thereby increasing TBI incidence.

The relationship between medication use and fall vulnerability has not been well-researched, but the emerging literature suggests a definite relationship between polypharmacology and deleterious outcomes for geriatric individuals (Maher, Hanlon &Hajjar, 2014). One research group from the Netherlands performed a literature search for articles

published between 1966 and 2008 regarding the risk of falling in elderly persons who use Non-Steroidal Anti-Inflammatory Drugs (NSAID). The meta-analysis concluded that "an increased risk for accidental falls is probable when elderly individuals are exposed to NSAIDs" (Hegeman, van den Bemt, Duysens, & van Limbeek, 2009, p. 496). Another study of 300 community-dwelling individuals found that polypharmacy was a risk factor in a surprising 79% of emergency department visits for falls in the elderly (Russell, Hill, Blackberry, Day, & Shyamali, 2006). A meta-analysis of 177 studies examining the relationship between psychotropic medications and the risk of falls in the elderly found that the odds ratio between the use of psychotropic drugs and falls are 1.78 and 1.57–2.01 respectively. In simple terms, the use of psychotropic medications by the elderly approximately doubled their chance of falls. The authors note that this information had little impact on the prescribing habits of physicians (Bloch et al., 2011).

Other obfuscating factors in conducting research on geriatric TBI incidence include failure to seek care and an underreporting of fall severity to a healthcare provider (Stevens et al., 2012).Research on rates of falls among the elderly are found for those who received medical attention. It can, however, be assumed that there is also a population of geriatric individuals for whom there was no formalized medical intervention. Hence, the prevalence of TBIs in the elderly population is unknown, but loose projections can be extrapolated from data on those who did seek medical care after a fall. The data derived from medically-reported TBIs shows that there were approximately 19.8 million emergency department visits by individuals ages 65 and older in the United States in 2009. In 2010, 19.4 million emergency department visits were by individuals ages 65 and older. Of those nearly 20 million emergency department visits, an estimated 25% were for injuries (Centers for Disease Control, 2009; Centers for Disease Control,

2010). Of these reported injuries, an estimated 237,000 annual emergency department visits by individuals age 65 and older were for MVCs (Vogel, Ginde, Lowenstein, & Betz, 2013), with an unknown number of emergency department visits related to falls. Given the higher incidence of TBIs associated with falls and MVC, it can be assumed that some percentage of the latter group of individuals incurred a TBI.

There is a major limitation concerning the above data: The statistics do not include medical services administered at non-reporting emergency departments, urgent care centers, or medical providers outside of reporting medical facilities. Also, the statistics do not account for individuals who were never seen by a medical professional. Given all these limitations, it is clear is that the above estimates are likely significant underestimations of the true prevalence of geriatric TBI. In short, while the exact incidence of TBI in elderly individuals cannot be determined, it is highly probable that the rates of TBI and its cognitive and affective impacts are much higher than reported under the current system.

Another understudied aspect of geriatric TBI is the way that injury sequelae may manifest in dramatically different ways in older people than in their younger counterparts. As stated previously, research demonstrates that the brain's response to traumatic brain injury is variable with age, suggesting that the current understanding of TBI and its effects is not sufficient to provide a framework for understanding the specific and unique progression of brain injury and recovery in the elderly. Nevertheless, the impact of TBIs on quality of life and functioning are known to be pervasive. They are also an important factor in decisions regarding intervention and assistive approaches for the individual across all domains of functioning. TBIs affect daily functioning and self-care, interpersonal relationships, and career or outside responsibilities. In addition, the effects of brain injury can have more subtle and pervasive

repercussions, including emotional and fiscal distress for the individual, their family, community, and society. For all these reasons, it is critical to consider the progression and impact of TBI in elderly populations as a separate and significant public health concern, requiring further inquiry and study.

The effects of TBI are varied, but include impact on the domains of memory, executive functioning, and affective status. One of the misconceptions concerning the conceptualization of brain functioning is the archaic perspective that the domains of cognitive functioning are independent and isolated. The current model for conceptualization posits interconnectivity between the domains of cognitive functioning and cerebral plasticity after the brain has received an insult. This plasticity is attributable to emerging research on the cellular and molecular mechanisms of neuroprotection and plasticity (Vemuganti & Hall, 2017).

The following sections will summarize the domains of cognitive functioning as supported by associated research. The summaries below are unfortunately limited by current neuropsychological research that focuses on younger individuals. There is scant research on neuropsychological functioning by domain in elderly individuals, so this analysis will extrapolate from existing research to suggest an approximate picture.

TBI and Memory Problems

Individuals with TBIs frequently complain about memory deficits (Vakil, 2005). Rimel, Giordani, Barth, Boll, and Jane (1981) found that self-reports of memory problems are at rates of 59% after a TBI. However, overall, the literature on memory deficits is mixed. Early studies on memory impacts found no visual or verbal memory issues at one-month post-injury (Gentilini et al.,1985; Levin et al., 1987; Mathias & Coats, 1999). More recent inquiries, however, found a

poorer working memory at the three-month post-TBI interval (Newcombe, Rabbitt, & Briggs, 1994), as well as delayed recall problems at the five-month post-TBI stage (Stuss et al.,1985).

Given that there is a degree of intrinsic memory decline associated with aging itself, understanding and mapping the process of TBI-induced memory decline is critical to differentiating TBI sequelae from the memory decline that has traditionally been associated with aging. More research in this area will be critical to determining if TBI-induced memory loss differs in any significant way from age-related memory decline. In addition, many other questions remain thus far unanswered. For example, compared to age-related memory decline, does the trauma inherent in TBI-induced memory loss have a proportionally greater impact on procedural memory, crystallized knowledge, narrative memory, self-concept, and/or self-awareness?

TBI and Attention

Attention is also critical for effective daily functioning. Attention deficits have been documented even with mild TBI (Bigler & Snyder, 1995; Gentilini, Nichelli, & Schoenhuber, 1989; Mclean, Temkin, Dikmen, & Wyler, 1983; Stuss et al., 1989). Research has also found that individuals with TBIs have increased difficulty with sustained and dual-task attentional measures (Dockree et al., 2006). This type of deficit can be isolated on measures such as the Sustained Attention to Response Task (SART; Manly, Davidson, Heutink, Galloway, & Robertson, 2000; Manly, Lewis, Robertson, Watson, & Datta, 2002; Manly, Robertson, Galloway, & Hawkins, 1999; Manly et al., 2003; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997), the Dual-task Attention to Response Task (DART; Dockree et al., 2006), and the Test of Everyday Attention (TEA; Manly et al., 2001). As already noted, this analysis has a weakness: The clear majority of studies examining impacts of TBI have been performed on individuals who are under age 65.

Again, the poorly understood nature of differences between age-related decline and TBI sequelae is a major problem; TBI-induced attention problems in the elderly are likely overlooked by the traditional western medical approach as aspects of "normal" aging. This difference, however. is critical. When post-TBI attentional problems are appropriately identified, it is possible to intervene with neurocognitive rehabilitation. The construct of attention is not a siloed construct, but rather one that overlaps with memory and executive functioning skills.

TBI and Executive Dysfunction

Executive functioning (EF) is a nomenclature applied to the set of capacities that allow us to act with intention and forethought. Lezak's (1995) construct of executive functioning consists of "volition, planning, purposive action, effective performance" where each component "…involves a distinctive set of activity related behaviors" (p. 650). EF is necessary for successful adaptive self-direction (Horton & Reynolds, 2007). Similarly, EF has the ability to adapt to external demands such as regulation of emotion, behavior, and thought (Luria, 1980) as opposed to a more passive process of information engagement (Fuster, 1997; Stuss & Knight, 2002).

EF has been traditionally conceptualized as frontal lobe functioning, however, a newer neuropsychological conceptualization of EF posits a multi-axial involvement of the anterior-posterior, lateral and cortical-subcortical brain regions, with the frontal lobes as dominant in the process (Reitan & Wolfson, 1985). In line with this conceptualization, impairments in individuals with TBI are likely to involve a more global cerebral involvement instead of being localized to one area of the brain. In addition, in TBI patients, other associated comorbidities, such as diabetes or coronary artery disease conditions, can potentially further impair neurocognitive and neurobehavioral domains of functioning. The overarching concern is that

these conditions are difficult to differentiate, exacerbated by the fact that the likelihood of comorbidities increases with age.

TBI and Affective Dysfunction

To a significant degree, effective functioning relies on the ability to differentiate and regulate emotional aspects of experience—a capacity which can be disrupted by a TBI in subtle, unexpected, and highly variable ways. Affective disturbances are noted in individuals with a TBI (Borgaro, Prigatano, Kwasnica, & Rexer, 2003). For example, depression, a particularly insidious mood disturbance, is more prevalent following TBI (Bombardier et al., 2010). Depression is also a risk factor contributing to vulnerability to a TBI (possibly because of the use of psychotropic medications). Additionally, depression complicates recovery, impairs quality of life, and frequently increases comorbidities (Zatzick et al., 2008). A recent meta-analysis of 99 studies examined depression in adults following a non-penetrating TBI. It found that, overall, 27% met criteria for major depressive disorder or dysthymia, and 38% reported clinically significant symptoms of mood disturbance. The authors concluded that the odds of developing depression after a TBI are respectively more than five, three, and two times higher than people living in the general community, the family and friends of the person who sustained the TBI, and other medical patients (Osborn, Mathias, & Fairweather-Schmidt, 2014). However, this study had a limitation in that it did not record an age comparison data set, and therefore does not offer clarification on whether the rates of depression are higher in elderly individuals. Again, an overarching concern is that signs and symptoms that may present as depression or dysthymia may be the sequelae of a TBI.

This brief review of TBI impact by domain sketches the magnitude of the impact on memory, attention, executive functioning, and effect. Most of the research on the above-

mentioned domains has focused on younger individuals, again pointing tothe paucity of research on TBI impact in elderly populations.

TBI and Outcome in Elderly Populations

The existing research on the effects of TBIs on the elderly tends to track outcome indicators at a demographic level (mortality and morbidity), but does not track the neuropsychological profiles or everyday functioning of elderly individuals who have sustained a TBI. Individual functioning can be assessed with the Glascow Coma Score (GCS), an assessment tool used worldwide to assess the severity of a TBI. Research consistently supports that GCS and age are important outcome indicators in patients with severe TBI (Hukkelhoven et al., 2003; Maas, Marmarou, Murray, Teasdale, & Steyerberg, 2007). In Europe, the International Traumatic Coma Project (ITCP) database (Rusnak, Janciak, Majdan, Wilbacher, & Mauritz, 2007) was established to track the outcome of patients with severe TBIs. The ITCP lists data collected from 13 medical centers across Europe (in Austria, Bosnia and Herzegovina, Croatia, Macedonia, and Slovakia). It found that for100 patients aged 66 years and older who had initial GCS scores of 3 or 4, 76% died after admission to the ICU and 24% were discharged with an additional 13 patients dying within 1 year (Brazinova et al., 2010). Put differently, this research found that elderly individuals with severe head trauma had a one-year post-TBI mortality rate of 89%, thus providing further evidence that age and GCS severity are important indicators for long-term outcomes.

In a similar study in Taiwan, Cheng et al. (2014) found that mild traumatic brain injury is a significant risk factor for death in the elderly. This study provides evidence that all levels of TBI (mild/moderate/severe) are significant indicators of mortality for the elderly. The evidence supports the perspective that in the elderly, any type of head contusion, even those that are

deemed inconsequential by the medical profession due to the presentation of a high GCS, should be further evaluated and treated aggressively to provide a better outcome.

In the United States, a matched chart review study of patients who died in the first five years following a TBI found that death was associated with a pre-existing pathophysiological process. But the study was not able to determine whether there was an accelerated aging process because of the TBI. The authors suggested "much more research" and "the need for medical and lifestyle interventions" (Hirshson et al., 2013, p. 231). Though the findings are preliminary, this study suggests that more aggressive lifestyle-targeted interventions, in addition to thoughtful medical therapies, may help to shift the longitudinal outcome of elderly individuals with TBI.

Worldwide, the research shows that being elderly and suffering a TBI is associated with a more negative outcome than in younger individuals. A reconceptualization of TBI and the associated criteria that constitute a TBI is warranted, including increased preventative measures and immediate response interventions, to provide better care for the expanding geriatric population.

TBI and Associated Healthcare Costs

On the personal level, the negative outcomes for elderly TBI patients may be well established; however, the financial costs are impactful as well, if less clear. The medical costs for these patients result in a heavy financial burden on social services and governmental programs. For example, in 2010, the direct medical costs associated with TBI were estimated to be $11.5 billion in the United States (Centers for Disease Control and Prevention, 2013b). Based on the National Study on the Costs and Outcomes of Trauma (NSCOT) dataset, health care utilization and cost analysis in the United States found that the unadjusted mean for total cost of care per year was $77,872 in persons aged 55–64 years, $76,903 in persons aged 65–74 years, and

$72,733 in persons aged 75–84 years (Thompson et al., 2012). Siracuse et al. (2012) note that the median associated costs for each elderly patient admitted to the hospital for fall-related injuries was $11,000 while some patients incurred medical costs as high as $170,000. In 2007, 400,000 Medicare patients were hospitalized in the United States for fall-related injuries amounting to $4.4 billion for inpatient costs which does not include post-discharge care and residual disability (Siracuse et al., 2012).

Traumatic Brain Injury, Chronic Traumatic Encephalopathy, and Dementia

Although a causal relationship between TBI and dementia cannot be established without further investigation, TBI is frequently comorbid with dementia. Dementia involves threats to functioning in the areas of memory, attention, executive functioning, and effect.The impact of TBI on these areas of functioning does not seem to be uniform or even similar across individuals. The literature is mixed regarding the influencing factors that determine why one person with a TBI develops dementia while another person does not.

Dams-O'Connor et al. (2013) found that individuals with a history of TBI present with subtle but meaningful differences in dementia phenotype compared to individuals without a history of TBI. The authors stated that,

> Those with a history of TBI had better cognitive functioning in the areas of immediate and delayed memory and word fluency…but had worse psychiatric functioning…and slightly higher incidence of clinically significant depression. Those with TBI also had worse cardiovascular and cerebrovascular health and were taking a greater number of prescription medications…but those with TBI were more likely to have visual hallucinations, a gait disorder, recent falls, and motor slowness. (Dams-O'Connor et al., 2013, p. 206)

The association between TBI and dementia has been brought to light principally through the study of individuals who sustained repetitive head trauma and incurred a progressive neurodegenerative disease called Chronic Traumatic Encephalopathy (CTE; Thurman, Branche, & Sniezek, 1998).

CTE was first described in 1928 by a New Jersey medical examiner in an article, "Punch Drunk" (Martland, 1928), published in the *Journal of the American Medical Association*. Martland described the behavior of boxers and what is now generally accepted as the consequence of repeated head trauma. His description was later substantiated in 1936 by psychiatrist E.J. Carroll (1936) who wrote that boxers were "punch-drunk, punchy, goofy, slap-happy, cutting paper dolls, or slug nutty" (p. 706). Martland also credits Cassasa (1924) for the findings of these "widely disseminated minute hemorrhages" (p.314) visible only by microscopic examination. The associated constellation of symptoms was later termed *dementia pugilistica* (dementia of a fighter).

In the 1960s, the condition was renamed to Chronic Traumatic Encephalopathy as it was observed not only in boxers but athletes involved in sports such as hockey, professional wrestling (Omalu, Fitzsimmons, Hammers, & Bailes, 2010), rugby, and professional American Football (Omalu et al., 2006; Omalu, Hamilton, Kamboh, DeKosky, & Bailes, 2010; Saulle & Greenwald, 2012). Long-term symptoms included memory and motor dysfunction, depression, anger, substance abuse, and suicide (Omalu, Bailes, Hammers, & Fitzsimmons, 2010).

Recent medicolegal investigations by forensic pathologists have found that, although the brain may appear grossly unremarkable upon visual post-mortem examination, immuno-histo-chemical analyses can reveal "widespread cerebral tauopathy in the form of neurofibrillary tangles and neuritic threads without neuritic amyloid plaques" (Omalu et al., 2010, p. 132). Yet,

earlier cases published by the same authors reported the presence of "diffuse amyloid plaques, neuropil threads and neurofibrillary tangles in the neocortex," but not in the entorhinal cortex or hippocampus (Omalu et al., 2006, p. 1086). The presentation of tauopathy and beta amyloid pathology has been noted many years after a singular incident of traumatic brain injury (Johnson, Stewart, & Smith, 2012). Upon analysis of the discrepancy, the primary difference between the presence and absence of amyloid plaques was found to be genetic. Specifically, it depended on whether or not the individual had the Apolipoprotein E (ApoE) genotype of E3/E3 and E3/E4. Regarding ApoE genotype, it has been shown that individuals who inherit the ApoE4 gene quite frequently exhibit a 300–900% increase in the development of chronic posttraumatic neurodegeneration (Bales, Dodart, DeMattos, Holtzman, & Paul, 2002; Friedman et al., 1999; Nathoo, Chetty, Van, & Barnett, 2003; Nathoo, Chetty, Van, Connolly, & Naidoo, 2003; Teasdale & Nicoll, 1997). These findings are exciting since there is now a genetic method by which it is possible to predict possible sequelae of a TBI and provide appropriate interventions based on those predictions. Also, at some point in the future, it may be possible to inhibit the protein production of this gene and potentially prevent a dementia neuropathological process.

In addition to the postmortem neurohistological pathology, the effects of traumatic brain injury can be found by examining changes in the cerebral spinal fluid (CSF) which produces protein markers when there is damage to the brain. In one research study (Zetterberg et al., 2006), 14 amateur boxers (11 men and three women) and 10 healthy male non-athlete control patients underwent voluntary lumbar puncture 7-10 days after the amateur boxers had a boxing match; both the boxers and the non-athlete groups underwent another voluntary lumbar puncture 90 days later. The authors evaluated neurofilament light protein, total tau, glial fibrillary acidic protein, phosphorylated tau, and beta-amyloid protein 1–40 and 1–42 concentrations in

cerebrospinal fluid. They found that, compared to the controls, the amateur boxers showed acute elevations in neurofilament light protein, total tau, and glial fibrillary acidic protein, which are all markers for neuronal and axonal injury. Upon evaluation at the three-month mark, with no reported boxing during the intervening time for the athletes, the neurofilament light protein was still elevated compared to the controls, indicating a continued inflammatory process.The authors also noted acute neuronal and astroglial injury and longitudinal elevation of neurofilament light protein. The results demonstrate that there are long-term and potentially chronic inflammatory processes even with sub-concussive head trauma. Unfortunately, the authors did not evaluate associated cognitive and executive functioning and its potential correlation with protein elevation. The lack of literature in this area suggests yet another possible direction for future research.

The above studies provide data pertaining to cases in which there was only one incidence of head trauma. However, if there is repetitive trauma in the form of CTE, such as the type that would be experienced by athletes or individuals who fall frequently, exacerbated by a specific genotypic profile, this may set up a "perfect storm" of risk factors that may lead to symptoms that appear dementia-like, yet are the sequelae of brain injury. Such associated neuropathological features of CTE include brain atrophy, cavum septum pellucid, and amyloid-β, tau and TDP-43 pathologies, many of which can contribute to clinical syndromes of cognitive impairment. Similar chronic pathologies are also commonly found years after just a single moderate to severe TBI (Smith, Johnson, & Stewart, 2013).

This information supports the notion that both traumatic brain injury and dementia are neuroinflammatory processes. Compared to age and gender-matched controls, postmortem histological examinations of patients with a documented history of TBI found that, even years

after a single TBI, persistent inflammation can be found in the brain in the form of activated microglia and phagocytic macrophages. Moreover, they found ongoing white matter degeneration, leading to tissue atrophy long after the traumatic incident (Johnson et al., 2013). Finally, this same study also discovered that, although axonal pathology in the corpus callosum was almost non-existent for the control patients without a history of TBI, there was evidence of axonal pathology, secondary to TBI, observed in patients up to 18 years after the incident of head trauma. This axonal pathology was evinced by a decrease in myelin density, which translates to a decrease in the thickness of the corpus callosum, thereby slowing communication between the right and left hemisphere. It can also be assumed that, in post-TBI patients, there is a disruption in the subcortical regions of the brain contributing to the further disruption in memory, attention, executive functioning, and effect.

Human and animal TBI models (Chen, Johnson, Uryu, Trojanowski, & Smith, 2009; Chen et al., 2004; Gale, Johnson, Bigler, & Blatter, 1995) support this hypothesis of subcortical disruption. When subcortical disruption is combined with a genotypical profile significant for elevated risk of dementia, this combination may have relevance to the development of neurodegenerative conditions such as Alzheimer's disease and chronic traumatic encephalopathy in survivors of TBIs (Fleminger, Oliver, Lovestone, Rabe-Hesketh, & Giora, 2003; Graves et al., 1990; Guo et al., 2000; Molgaard et al., 1990; Mortimer, French, Hutton, & Schuman, 1985; Mortimer et al., 1991; O'Meara et al., 1997; Plassman et al., 2000; Salib & Hillier, 1997; Schofield et al., 1997).

There may be a way to classify the severity and extent of the functional impairment. In a post-mortem histological examination, McKee et al. (2013) found four distinct stages of chronic traumatic encephalopathy thatwere correlated with histological changes in clinical symptoms as

reported by families. Dams-O'Connor et al. (2013) note that "the clinical profile of post-TBI dementia seen in the current study does overlap considerably with the symptom presentation reported in individuals who have been diagnosed with CTE posthumously….[they] include mood and behavioral symptoms such as depression, irritability, and impulsivity" (p.206). In addition to these symptoms, there may also be associated motor symptoms such as gait disturbance, and slow motor response, as well as changes in memory and executive functioning (Corsellis, Bruton, & Freeman-Browne, 1973; Gavett et al., 2011; Martland, 1928).

Although little research on TBI and CTE focuses on geriatric populations, the mechanisms described in the preceding section can provide a lens through which neuropsychology may better understand the geriatric client. Although research on the impacts of TBI in elderly individuals is still neophytic, the literature appears to agree that how the brain responds to trauma may change across life stages.

Alzheimer's Disease: A Neuropsychological Perspective

Many elderly individuals with memory, attentional, effective, and executive dysfunction are diagnosed with Alzheimer's disease (AD). As outlined above, these symptoms could be the result of brain injury, combined with genotypical influences, contributing to an inflammatory process. The disproportionate degree of injury related to falls in geriatric patients complicates the differences between AD and the sequelae of TBI and CTE, as does the pattern of under-reporting in patients with pre-existent dementia. The question remains whether it is even possible to differentiate between the two symptomology profiles (Horton & Reynolds, 2007).

Neuropsychological assessment is effective in identifying predictive indicators for Alzheimer's disease (Storandt, Botwinick, & Danziger, 1984). Early symptoms of Alzheimer's disease which is observed by neuropsychological assessmentare seenin areas of learning and

memory (Hart, Kwentus, Taylor, & Hamer, 1988), verbal object category recall (Cahn et al., 1995; Lafletche & Albert, 1995; Rosen, 1980; Small, Herlitz, Fratiglioni, Almkvist, & Bäckman, 1997), and naming alphabetically associated words (Monsch et al., 1992; Salmon, Heindel, & Lange, 1999). It is hoped that better delineation of neurodegenerative processes consistent with dementia can help provide a better framework for differentiation between the two processes.

Method

This dissertation presents a case study of a single elderly patient who experienced the phenomenon (TBI) of interest to the investigation. For many decades, single case designs have been promoted as a feasible way for practicing clinicians to convey important clinical information even if they do not have access to the same resources as non-practicing, university-based research scientists (Barlow & Hersen, 1973; Browning & Stover, 1971; Chassan, 1967; Hayes, 1981; Hersen & Barlow, 1976; Kazdin, 1978, 1980, 2003; Leitenberg, 1973; Svenson & Chassan, 1967). Clinical case studies are an important research modality because research can provide critical information that is frequently overlooked or ignored in quantitative research. The single case research design is one method by which it is possible to take unique, consolidated information, collected under less than ideal conditions, and then extrapolate worthwhile insights. This dissertation used a mixed methods approach and a philosophical framework of pragmatism.

Pragmatism's philosophical basis for research, as described by Creswell (2013), outlines a worldview that does not assume a unitary construct of reality. Based on the notion that there is more than one way to interpret standardized data, this philosophical paradigm enables a mixed methods approach. Within this multi-disciplinary approach, the researcher has freedom of choice and may forego accepting the world as "an absolute unity"(Creswell, 2013, p.11). This outcome-

driven theoretical stance is important to constructing a clinical case study based on a single case research design since it incorporates both inductive and deductive approaches.

Single Case Research Design

This case study will adhere to the modality of Single Case Study Research Design (SCRD) as outlined by Kazdin (1980). Analysis of the available data set represents an examination of a naturally occurring set of events that was not designed by the researcher. Data evaluation in the SCRD approach is primarily through visual inspection, most often graphing, with statistical analysis as an infrequent adjunctive component. Because the events have no control group for comparison and there is no standardized measurable intervention, the research cannot eliminate the influence of outside factors. Hence, the analysis in this dissertation should be considered a "pre-experimental design" (Kazdin, 1980, p. 87),and a forerunner of more standardized and robust research.

In addition, because any conjecture about the pre-morbid functioning of the patient is purely speculative, based upon qualitative analysis of reporting by collaterals, the patient cannot serve as his own control (as is done in some more experimentally-based single case study designs). Thus, only speculative conclusions can be drawn from this study. That said, the repeated application of standardized measures at intervals over a prolonged period can provide strong evidence of change occurring over time for this individual. Further, while any conclusions will be applicable only to this individual and cannot be generalized to a larger population, such conclusions can provide an important initial modeling of the deterioration process. Though single case design is not as robust as true experimental designs, valid inferences regarding correlation can still be drawn.

In terms of worldview, this type of case study exists within the construct of a *quantitative descriptive paradigm* created by Gast & Ledford (2014). Their quantitative descriptive construct includes identifying at least one variable to investigate. For this dissertation, the variable under study was the patient's performance over time on intelligence and memory standardized measures. There is also the use of a systematic measurement system as a component of this approach. In terms of research design, Gast and Ledford (2014) consider this application of repeated measurement to be an "A" *design* that represents a purely descriptive investigation with no intervention by the investigator and can be considered an extended baseline condition. This approach is also considered an appropriate methodology in the case of rare or understudied phenomena (Gast & Ledford, 2014) for which this dissertation qualifies given the dearth of papers reporting longitudinal neuropsychological outcomes in geriatric individuals who have a history of TBI.

Any investigation involving quantitative discussions must consider issues of validity. Because an extended baseline design cannot control for confounding variables or hypothesize a causative relationship between independent and dependent variables, it cannot claim to be either internally or externally valid. However, it is possible to make correlational observations and suggest directions for future research. One strength of this dissertation's case study is that the psychometric measures employed have robust construct validity, having been extensively normed under the auspices of the Pearson corporation.

A single case study design considers past and future projections of performance analyses, the immediacy and magnitude of the change, and uses multiple and heterogeneous patients. For this case study, the investigator identified a patient who received multiple neuropsychological

evaluations by different individuals at different points in time. These multiple points of measurement add inter-rater reliability and validity to the collected data.

Historical perspectives approach

Gast & Ledford's (2014) "Historical Perspectives Approach" offers additional direction on single case research methodology where the goal for the study is an investigation of emerging evidence about a topic, the rationale for investigation and identification of the next steps, leading to a purpose statement which guides research questions. For this dissertation, there is a paucity of information in the literature concerning the longitudinal effects of TBI in elderly patients. The literature search considered a body of evidence that includes corollary information from the fields of neuroscience and medicine. These related lines of research support the general statement, as seen above, that there is a pressing need for a more accurate understanding of this phenomenon. Important directions for future research include further longitudinal neuropsychological evaluations and a combination of case data to provide a higher number of individuals for a more robust quantitative evaluation. This study proposes to increase the level of knowledge in this understudied field through in-depth analysis of longitudinally collected raw data available in a specific case of TBI in an elderly patient.

Case Study

Background

This dissertation used a variety of sources to reconstruct the history of this case, including clinical notes, previous neuropsychological evaluations, data collected at the most recent neuropsychological evaluation, and an in-person interview with the patient's wife. At the time of the final evaluation, (which was the only evaluation conducted by the author), the

patient's verbal skills had deteriorated to the extent that he could not communicate in any comprehensible way regarding events in his life, past or present.

In 2009, the patient, a 68-year-old college-educated Caucasian male, was driving a large SUV with his wife as a passenger. They sustained a driver-side collision and the patient hit his left forehead on the driver side window. There was no reported loss of consciousness. By his spouse's account, the patient was ambulatory and disoriented. The patient was not transported to the hospital for medical evaluation at the time of the accident. Over the ensuing days, the patient's behavior became increasingly erratic, and there was evidence of cognitive impairment, memory problems, and executive dysfunction such as financial impulsivity. In the ensuing weeks, the patient's ability to function deteriorated such that he was dismissed from his longtime consulting position, in which he had obtained significant professional and financial success.

Neurological imaging obtained after the MVA demonstrated mild-to-moderate diffuse volume loss and mild chronic microvascular changes. This is consistent with neurological imaging performed on the patient five years which showed mild cerebral volume loss with the presence of mild periventricular white matter disease. All other aspects viewed in the neuroimaging were non-remarkable.

Records indicated that the patient had sustained concussions in the sixth and ninth grade (age 11 and 14 respectively) with the second concussion associated with unconsciousness. In his early adulthood, he received an electrical shock to the right ear from an exposed wire which was sufficient to throw him across the room. At age 58, the patient fell and hit the occipital cranial region of his head. Although he made no complaints of post-concussive symptoms at the time, he sustained a permanent change in his sense of taste and smell per his partner. A Computerized

Tomography (CT) scan, five years after the concussion at age 58 (in 2004), showed mild cerebral volume loss in his brain.

An MRI performed five weeks after the car accident (in 2009) indicated mild microvascular changes and mild cerebral atrophy that was consistent with the imaging five years earlier. His medical records are otherwise unremarkable and there is no report of any psychiatric history.

Data

Neuropsychological testing provides a modality by which the cognitive and functional ability of an individual can be assessed in a manner that reveals impairments that current neuroimaging is unable to assess (Lezak, Howieson, Bigler, & Tranel, 2012). Clinical interviewing may be inaccurate as the patient's experience and reporting may be inaccurate (Edmonds, Delano-Wood, Galasko, Salmon, & Bondi, 2014). Conversely, the clinician may also be inaccurate regarding the degree of the patient's impairment from diagnostic assessment bias (Alegría et al., 2008). Neuropsychological assessment can be divided into various domains for evaluation. The domains are as follows: Intellect, Memory, Executive Functioning, Sensorimotor, Attention, Language, Visual-spatial, and Emotion.

Chronology of Neuropsychological Assessments

The patient received four neuropsychological evaluations within 49 months of the motor vehicle collision (MVC). The first neuropsychological evaluation was at the 3-month timeframe after the MVC, with remaining subsequent evaluations at the 8-month, 19-month and 49-month mark respectively.

Instruments Used in Each Neuropsychological Evaluation

A variety of assessment instruments were used for the various neuropsychological evaluations (see Appendix A). The first neuropsychological evaluation at three months post-MVA incorporated the following assessment items: the Wechsler Memory Scale Third Edition (WMS-III), The Wechsler Adult Intelligence Scale Third Edition (WAIS-III), Trail Making Test (TMT) Part A and B, Rey Osterrieth Complex Figure (ROCF) and 30-minute delay, Wisconsin Card Sorting Test (WCST), Finger Tapping Test (FTT), Minnesota Multiphasic Personality Inventory-2 (MMPI-2), and Boston Naming Test (BNT).

The second evaluation at the 8-month timeframe, the patient was only administered the Rivermead Behavioral Memory Test (RBMT) while for the third neuropsychological evaluation at the 19-month mark post-MVA involved the administration of: the Wechsler Memory Scale Third Edition (WMS-III), The Wechsler Adult Intelligence Scale Third edition (WAIS-III), Trail Making Test (TMT) Part A and B, Rey Osterrieth Complex Figure (ROCF) and 30 minute delay, Finger Tapping Test (FTT), Test of Memory Malingering (TOMM), Fuld Object-Memory Evaluation, Wide Range Achievement Test (WRAT), Controlled Oral Word Association Test (COWAT), Boston Naming Test (BNT), Name Writing, Aphasia Screening, and D-KEFS C/W Interference.

The fourth neuropsychological evaluation at the 49-month time frame,the patient was administered the Wechsler Memory Scale Third Edition (WMS-III), The Wechsler Adult Intelligence Scale Third Edition (WAIS-III), Rivermead Behavioral Memory Test (RBMT), and the Behavioral Assessment of Dysexecutive Syndrome (BADS), and Scales of Independent Behavior- Revised (SIB-R).

Analysis

This chapter reveals evaluated neuropsychological domains, the patient's corresponding scores, and concludes with a brief discussion of the data. The detailed psychometric properties for each assessment were outside the scope of this dissertation. For further information on the precise psychometric properties, refer to the individual administration manual or Strauss, Sherman, and Spreen's (2006) *A Compendium of Neuropsychological Tests: Administration, Norms, and Commentary.*

Domain: Intellect

Wechsler Adult Intelligence Scale-Third Edition. Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 1997a, 2002) is an individually administered assessment tool for adult intellectual ability in individuals aged 16 to 89 years. The WAIS-III has three composite scores: Verbal IQ (VIQ), Performance IQ (PIQ), which together construct the Full-Scale IQ (FSIQ).

Verbal expression is one of the best indicators of overall intelligence. The Verbal IQ (VIQ) is comprised of two factor-based indices: the Verbal Comprehension Index (VCI) and Working Memory Index (WMI). The VCI requires verbal conceptualization of stored knowledge. The VCI is constructed from three subtests: Vocabulary, Similarities, and Information. Vocabulary subtests consist of the patient providing oral definitions for words. Similarities subtests consist of the patient stating how two objects or concepts are similar. Information subtests consist of the patient orally responding to questions about the information. The Working Memory Index (WMI) assesses working memory processes applied to the manipulation of orally presented verbal sequences. The WMI involves attention, concentration, mental control, and reasoning. The WMI is constructed from three subtests with the

Comprehension subtest as an adjunctive test. The three primary subtests are Arithmetic, Digit Span, and Letter-Number Sequencing, with Comprehension as an additional measure which can be administered if one of the other subtests are found to be invalid. The Arithmetic subtest assesses a patient's ability to solve orally presented arithmetic word problems within a specific time limit. The Digit Span subtest assesses a patient's ability to verbally repeat forward and backward an orally presented sequence of numbers. The Letter-Number Sequencing assesses a patient's ability to listen to a combination of numbers and letters and then recall the numbers and place the numbers in ascending order and the letters in alphabetical order. The Comprehension subtest can be used as an additional measure to construct the WMI, and is comprised of questions that require an understanding of concepts and socially constructed practices.

The Performance IQ (PIQ) is constructed from two factor-based indices: Perceptual Organization Index (POI) and Processing Speed Index (PSI). The POI requires visual perception, organization, and reasoning with visually presented information and nonverbal material to solve problems that are not taught in formal education. The POI subtests include Picture Completion, Block Design, and Matrix Reasoning. The Picture Completion subtest assesses the patient's ability to view a picture and point to or name the important part that is missing. The Block Design subtest assesses the patient's ability to replicate models or pictures of two color designs with blocks. The Matrix Reasoning subtest assesses the patient's ability to look at a matrix with the section missing and identify by pointing to or verbally responding to one of five response options. The PSI requires visual perception organization, visual scanning, and executive control required to assess simple visual material as quickly as possible. The Processing Speed Index (PSI) is comprised of two main subtests Digit Symbol and Symbol Search. The Digit Symbol subtest consists of an exercise where the patient must copy symbols paired with numbers within

two minutes. In the other part of the Digit Symbol subtest, numbers are given to the patient who must then write down as many symbols as can be recalled. The Symbol Search subtest requires the patient to determine whether two selected symbols match any of the symbols in a search group in two minutes or less. Adjunctive subtests can be used to supplement the PSI, and include Picture Arrangement where the patient arranges cards to create a logical story, and Object Assembly where the patient is presented with puzzle pieces that must be put together to create an object (Strauss et al., 2006). The patient's results for the WAIS-III at the 3-month, 19-month and 49-month evaluation are below in Table 1:

Table 1

Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) Composite index Results at 3-month, 19-month and 49-month evaluation

Subtests	3-month	19-month	49-month
Verbal IQ	99	82	59
Verbal Comprehension Index	107	94	57
Performance IQ	104	92	60
Perceptual Organization Index	103	95	67
Full-Scale IQ	101	86	56
Working Memory Index	* --	* --	61
Processing Speed Index	* --	* --	63

*Notes: * -- No data is available*

The changes of composite scores of the VIQ and the PIQ were evaluated between the 3-month and 19-month evaluation as well as the 19-month and 49-month evaluation using a *t*-test.

A paired-sample *t*-test was conducted to compare the WAIS-III composite score results between the 3-month and 19-month evaluation, and there was no significant difference noted 3-month (M=101.5, SD=3.535) and 19-month (M=87, SD=7.071) conditions; t(2)=2.594, p=0.122. Yet when the same statistical analysis was performed comparing the 19-month and 49-month WAIS-III composite scores (VIQ and PIQ), there emerged a significant difference between the scores for 19-month (M=87, SD=7.07) and 49-month (M=59.5, SD=0.707) conditions; t(2)=5.473, p=0.032.

A paired-sample *t*-test was conducted to compare the WAIS-III composite score results between the 3-month and 19-month evaluation for the VCI and POI, and there was significant difference noted 3-month (M=105, SD=2.82) and 19-month (M=94, SD=0.707) conditions; t(2)=5.093, p =0.036 . When the same statistical analysis was performed comparing the 19-month and 49-month WAIS-III VCI and POI, there emerged a significant difference between the scores for 19-month (M=94.5, SD=0.707) and 49-month (M=63, SD=5.65) conditions; t(2)=7.814, p=0.016.

Other statistical evaluations for the composite scores are not possible as subtests constructing the WMI and PSI were not performed. Qualitatively, an overall decrease in performance is noted over time for the VIQ, VCI, PIQ, and FSIQ.

Given that there was a decrease on all of the subtests, a question arose as to whether there was a difference in the rate of deterioration between the neuropsychological evaluations when controlling for time with the assumption that there is a linear rate of change over time. Table 2 represents the average rate of change in various WAIS-III composite scores changes per month between the neuropsychological evaluations.

Table 2

Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) Composite estimated changes between 3-month and 19-month and19-month and 49-month assessments

Subtests	3-month to 19-month change in score	19-month to 49-month change in score
Verbal IQ (VIQ)	-1.0625	-0.733
Verbal Comprehension Index (VCI)	-0.8125	-1.166
Performance IQ (PIQ)	-0.75	-1.066
Perceptual Organization Index (POI)	-0.50	-0.933
Full Scale IQ (FSIQ)	-0.9375	-0.633
Working Memory Index	* --	* --
Processing Speed Index	* --	* --

*Notes: * No data is available*

The data clearly shows an increase in deterioration rate for all composite indices, but the rate of change for VIQ and PIQ is not statistically significant when performing a *T*-test for two sample assuming equal variances for 3-month to 19-month change (M=-0.906, SD=0.220) and 19-month to 49-month (M=-0.899, SD=0.235) conditions; t(2)=-0.030, p = 0.490. The same conclusions are drawn when evaluating the rate of change for VCI and POI when performing a *T*-test for two sample assuming equal variances for 3-month to 19-month change (M=-0.656, SD=0.221) and 19-month to 49-month (M=-1.0495, SD=0.1647) conditions; t(2)=2.018, p = 0.181.

The scaled scores on the subtests on the WAIS-III for the 3-month, 19-month, and 49-month evaluations were more closely examined. A two-sample *T*-test assuming equal variances was performed on available scale scores between the 3-month and 19-month evaluation as seen in Table 3:

Table 3

Results of t-test and Descriptive Statistics for WAIS-III subtest scale scores between the 3-month and 19-month evaluation

	3-month evaluation		19-month evaluation		95% CI		
Outcome	M	SD	M	SD		T	df
	10.272	2.284	7.909	2.773	[0.104, 4.623]	2.182*	20

Note: * p < .05.

There was a significant difference between the scaled scores for 3-month (M=-10.272, SD=2.284) evaluation and 19-month (M=7.909, SD=2.773) evaluation; t(20)=2.182, p = 0.041. The same was also true for the comparison between the 19-month and 49-month evaluation:

Table 4

Results of t-test and Descriptive Statistics for WAIS-III subtest scale scores between the 19-month and 49-month evaluation

	19-month evaluation		49-month evaluation		99% CI		
Outcome	M	SD	M	SD		T	df
	7.909	2.773	3.4	3.162	[1.027, 7.882]	3.70*	20

Note: * p < .01.

There was a significant difference (p<0.01) between the scaled scores for 19-month (M=7.909, SD=2.773) and 49-month (M=3, SD=3.162) conditions; t(20)=3.70, p = 0.01. The subtests associated with the VCI, WMI, POI, and PSI were then examined individually to better understand the significance of the above findings.

The VCI was constructed from three subtests: Vocabulary, Similarities, and Information. When the three subtests of the VCI were compared between the 3-month and 19-month

evaluations, there was no statistically significant difference between the 3-month (M=-11.333, SD=2.309) and 19-month (M=9, SD=3.464) conditions; t(4)=0.971, p = 0.193) nor between the 19-month (M=-9, SD=3.464) and 49-month (M=2.66, SD=2.081) conditions; t(4)=2.714, p = 0.053.

The WMI is constructed from Arithmetic, Digit Span with Comprehension used as an additional measure in lieu of Letter-Number Sequencing which was not administered until the 49-month evaluation. When the three subtests of the WMI were evaluated, there was no statistically significant difference between the 3-month (M=8.666, SD=1.527) and 19-month (M=5, SD=2.0) evaluation; t(4)=2.524, p = 0.065), or the 19-month (M=5, SD=2) and 49-month (M=3.333, SD=2.081) evaluation; t(4)=1.00, p = 0.374.

These POI subtests include: Picture Completion, Block Design, and Matrix Reasoning. There was no statistical difference between the 3-month (M=10.666, SD=3.511) and 19-month (M=9.333, SD=1.527) evaluation; t(4)=0.603, p = 0.579) nor between the 19-month (M=9.333, SD=1.527) and 49-month (M=5, SD=5.19) conditions; t(4)=1.386, p = 0.238).

The Processing Speed Index (PSI) is comprised of Digit Symbol and Picture Arrangement used in lieu of Symbol Search which was administered only in the 49-month evaluation. There was no statistical difference between the 3-month (M=10.666, SD=0.707) and 19-month (M=8.5, SD=2.12) evaluation; t(2)=1.265, p = 0.333) There was no statistical difference between the 3-month (M=8.5, SD=2.12) and 19-month (M=2.5, SD=0.707) evaluation; t(2)=3.795, p = 0.063.

The per month changes in scale scores between administrations of the WAIS-III are noted in Table 5.

Table 5

WMS-III Subtest average monthly changes in scale scores between 3-month and 19-month evaluation and 19-month and 49-month evaluation

Subtests	Average change in scale score between 3-month and 19-month evaluation	Average change in scale score between 19-month and 49- month evaluation
Vocabulary	0.0625	-0.2
Similarities	-0.3125	-0.1333
Information	-0.1875	-0.3
Arithmetic	-0.1875	-0.0666
Digit Span	-0.125	-0.03333
Comprehension	-0.375	-0.0666
Picture Completion	0.0625	0.1
Block Design	-0.125	-0.2666
Matrix Reasoning	-0.1875	-0.333
Digit Symbol	-0.0625	-0.2666
Coding	* --	* --
Picture Arrangement	-0.1875	* --
Symbol Search	* --	* --
Letter number sequencing	* --	* --
Object assembly	* --	* --

Note: * No data is available

For the subtests associated with the VCI, the Vocabulary subtest saw a scale score change of 0.0625 scale scores per month between the 3-month and the 19-month evaluation and a

change of -0.2 scale scores per month between 19-month and 49-month evaluations. For the Similarities subtest, there was a change of -0.3125 scale scores per month between the 3-month and the 19-month evaluation, and then -0.1333 scale scores per month between the 19 and 49-month evaluation. The Information subtest saw a change of -0.1875 scale scores per month between the 3-month and 19-month evaluation, and -0.3 scale scores per month between the 19-month and 49-month evaluation.

For the subtests associated with the WMI, Arithmetic showed a change of -0.1875 scale scores per month between the 3-month and 19-month evaluation, and then the rate of decline decreased to -0.0666 scale scores per month between the 19-month and 49-month evaluation. For Digit Span, the change between the 3-month and 19-month evaluation was -0.125scale scores per month that shifted to -0.0333 scale scores per month between the 19-month and the 49-month evaluation. For Comprehension, there was an initial rate -0.375 scale scores per month between the 3-month and 19-month evaluations, and -0.0666 scale scores per month between the 19-month and 49-month evaluation.

For subtests of the POI, Picture Completion showed a change of 0.0625 scale scores per month between the 3-month and 19-month evaluations and 0.1 scale scores per month between the 19-month and 49-month evaluation. For Block Design the rate of decline was -0.125 scale scores per month between the 3-month and 19-month evaluation and then -0.2666 scale scores per month between the 19-month and the 49-month evaluation. For the Matrix Reasoning subtest, the rate of change was -0.1875 scale scores per month between the 3-month and 19-month evaluation and then -0.333 scale scores per month from the 19-month to the 49-month time frame.

For the subtests of the PSI, the rate of change for the Digit Symbol subtest was -0.0625 scale scores per month between the 3-month and 19-month evaluation and -0.2666 scale scores per month between the 19-month and 49-month evaluation. The other subtest for the PSI, Symbol search, was not administered for the first two administrations of the WAIS-III, but for the third administration at the 49-month evaluation the scale score is 3. It is impossible to estimate the rate of change in scale score over time for this subtest.

What can be seen in Table 5 is that all the domains, except for the VCI, have a consistent timeframe, regarding the time in which there is the faster deterioration. As can be seen, the WMI shows the most decline in the timeframe closer to the TBI, yet the POI and PSI rate of decline accelerates farther out from the time of the trauma. The VCI is split and this may be due to the inclination of the language cortex following a TBI with the language constructs, which are most concrete and formally learned, deteriorating later than the part of the language cortex that deals with more abstract reasoning and relational constructs.

Domain: Memory

Wechsler Memory Scale-Third Edition. According to the *Handbook of Normative Data for Neuropsychological Assessment, Second Edition* (Mitrushina, Boone, Razani, & D'Elia, 2005), the Wechsler Memory Scale-Third Edition (WMS-III; Wechsler, 1997b, 1997c, 2002) consists of a battery of 11 subtests focused on learning memory and working memory. There are six subtests in the core battery and five additional subtests that are optional or supplemental. Combining WMS-III norms with WAIS-III allows joint factor index scores to permit ability and memory comparisons. The change in the WMS-III from the WMS-II included increased scoring sensitivities by extending the floor and raising the ceiling on the associated scale scores. The standardization sample for the WMS-III included 1032 adults who were selected to be

representative of US adults age 16 to 89 years in 1995. Standardization test sites were derived from four regions of the United States, including the Northeast, North-central, South, and West. The sample was stratified for age, sex, race, ethnicity, educational level, and geographic region. Performance on the WMS-III batteries is positively correlated with IQ.

The WMS-III has three primary index scores: Immediate Memory, General Memory, and Working Memory. The primary index scores are constructed from the six primary subtests while the five optional subtests are also available. The primary subtests for Auditory Presentation include Logical Memory parts one and two, Verbal Paired Associates parts one and two, and letter number sequencing. Optional tests for the auditory presentation include Information and Orientation, Word Lists parts one and two, Mental Control, and Digit Span. The primary subtests for Visual Presentation include Faces parts one and two, Family Pictures parts one and two, and Spatial Span. Optional Tests for Visual Presentation consists of Visual Reproduction parts one and two (Strauss et al., 2006).

Part of the difficulty with the evaluation of this patient was the incomplete administration of the WMS-III, which means that the indices are not available for the purposes of this research. The available scaled scores for the composites are noted in Table 6, and subtest scaled scores are noted in Table 7.

Table 6

Wechsler Memory Scale-Third Edition (WMS-III) Composite Scaled Score Results at 3, 19 and 49-month evaluation

Subtests	3-month	19-month	49-month
Auditory Immediate	* --	7	5
Visual Immediate	* --	* --	6

Immediate Memory	* --	* --	11
Auditory Delayed	* --	9	6
Visual Delayed	* --	* --	6
Auditory Recognition Delayed	* --	3	1
General Memory	* --	* --	13
Working Memory	* --	* --	* --

Note: * No data is available

Table 7

Wechsler Memory Scale-Third Edition (WMS-III) Subtest scaled score Results at 3-month, 19-month and 49-month evaluation

Subtests	3-month	19-month	49-month
Logical Memory Immediate	6	3	1
Logical Memory Delayed	6	4	1
Logical Memory Recognition	* --	* --	1
Verbal Paired Associates Immediate	Discontinued	4	4
Verbal Paired Associates Delayed	* --	5	5
Verbal Paired Associates - Recognition	* --	* --	6
Visual Reproduction Immediate	4	2	1
Visual Reproduction Delayed	5	5	4
Visual Reproduction Recognition	8	6	1

Orientation	* --	14 out of 14	* --

Note: * No data is available

For the second and third administration of the WMS-III, it must be noted that, the patient had a raw score of 0 for both the administration and the recall of Verbal Paired Associates I and II. In WMS-III scoring, this leads to a scale score of 4 for the Verbal Paired Associates I recall scale score, and a scale score of 5 for the Verbal paired associates II recall that leads to the appearance of an over-inflation of ability. When the same raw scores are calculated using the more current version of the WMS, the WMS-IV, the patient would receive a scale score of 1 for both items.

A paired-samples *t*-test assuming equal variance was conducted to compare the WMS-III Logical Memory Immediate and Delayed scaled score results at the 3-month versus the 19-month evaluation. For this *t*-test Logical Memory Recognition was omitted as there was no administration at the 3-month and 19-month administration. There was a significant difference between the scores for 3-month (M=6, SD=0) and 19-month (M=3.5, SD=0.707) conditions; $t(2)=5.000$, $p = 0.038$ as well as the between the 19-month (M=3.5, SD=0.707) and 49-month (M=1, SD=0) conditions; $t(2)=5.000$, $p = 0.038$.

For Verbal Paired Associates, it is impossible to evaluate the variation between the 3-month and 19-month evaluation as the Verbal Paired Associates administered at the 3-month evaluation was discontinued due to the patient being overwhelmed. Although it is impossible to do a quantitative evaluation, there are important qualitative data on the patient's ability to process auditory information and his affective response of being overwhelmed and anxious. For the 19-month and the 49-month administration although the patient did not become overwhelmed he received a raw score of 0 for both administrations.

For the Visual Reproduction Immediate, Delayed, and Recognition subtest, the paired-samples *t*-test showed that there was no significant difference between the scores for 3-month (M=5.66, SD=2.080) and 19-month (M=4.33, SD=2.080) conditions; t(4)=0.784, p = 0.477 nor for the 19-month (M=4.33, SD=4.2.080) and 49-month (M=2, SD=1.732) conditions; t(4)=1.492, p = 0.210.

When the same WMS-III constructs were evaluated looking at the scaled score change rate over time (see Table 15), the monthly decline appears to be most marked in the 3-month to 19-month time, with an average decline of -0.125, and then it tapers out in the subsequent timeframe. It is interesting to note that although there is a decline in functioning, there is memory consolidation that occurs between the immediate administration and the delayed administration with greater proficiency noted in the recognition phase for Logical Memory Verbal Paired Associates and Visual Reproduction. It is also interesting to note that the orientation is noted at 14 out of 14 at the 19-month evaluation despite the obvious impairments in memory.

When comparing functioning on the WMS-III to the subtest constructing the WMI on the WAIS-III, it is noted that functioning on the Arithmetic subtest in all three evaluations is notably higher (SS=10, 7, 5) compared to the scale scores for the subtests of the WMS-III. Digit span and Comprehension scale scores are consistent with the recognition scale scores on the WMS-III.

The changes in scale scores per month between the 3-month and 19-month evaluation, and the 19-month and 49-month evaluation are noted in Table 8.

Table 8

Wechsler Memory Scale Third Edition (WMS-III) Changes in scale scores per month between 3-month and 19-month evaluation and 19-month and 49-month evaluations

Subtests	Change in scaled scores between 3-month and 19-month evaluations	Change in scaled scores between 19-month and 49-month evaluations
Logical Memory Immediate	-0.1875	-0.0666
Logical Memory Delayed	-0.125	-0.1
Logical Memory Recognition	* --	* --
Verbal Paired Associates Immediate	* --	0.00
Verbal Paired Associates Delayed	* --	0.00
Verbal Paired Associates - Recognition	* --	* --
Visual Reproduction Immediate	-0.125	-0.03333
Visual Reproduction Delayed	0	-0.0333
Visual Reproduction Recognition	-0.125	-0.1666
Orientation	* --	* --

*Note:** No data is available

For Logical Memory Immediate and Logical Memory Delayed, as well as Visual Reproduction Immediate, there is a decrease in rate of decline between the 19-month and 49-month evaluation. Yet, the opposite is seen for Visual Reproduction Delayed and Recognition, as there is an acceleration in the rate of scale score decline between the 19-month and 49-month evaluations.

Rivermead Behavioural Memory Test. Although the WMS-III is considered the "Gold Star" standard for memory evaluation, the skill set does not necessarily translate over to everyday memory functioning tasks. The Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) is a short test originally designed to assess memory functions for

rehabilitation in adults with acquired neurological dysfunction (Cockburn & Keene, 2001; Wilson, Cockburn, Baddeley, & Hiorns, 1989). The RMBT was normed on 118 control patients between ages 16-69 years with a mean IQ of 106 (range 68-136), and can be administered in about 25 minutes (Wilson et al., 1989). The RBMT consists of 11 subtests: subtest numbers one and two, titled First and Second Names, involve the patient being shown portraits and asked to recall the first and last names after a delay. Subtest three, Belonging, consists of the examiner "borrowing" and hiding a personal belonging of the patient. At the end of the test, the patient must be able to remember the belonging and where it was placed. Subtest four, Appointment, consists of the patient being asked to recite a certain question when an alarm sounds. Subtest five, Picture Recognition, consists of the patient being presented with line drawings and after a delay of time, the patient must distinguish between the drawings that were and were not presented. Subtest six consists of the patient listening to a story and then recalling the story immediately and then after a delay. Subtest seven, Face Recognition, consists of the patient being presented a sequence of faces. After a delay of time, they must be able to distinguish the presented faces from faces that had not been previously presented. Subtest eight, Route, consists of the patient being shown a series of movements by the examiner with the patient having to replicate the route immediately and again after a time delay. Subtest nine, Messages, consists of the patient being able to retrieve an object left along the route during the previous subtest. Subtest 10, Orientation and Date, consists of the patient being asked questions by the examiner related to mental status and orientation. The scoring for the RBMT is different than the WMS-III as there are no scaled scores rather each item is allocated 2 points (normal), 1 point (borderline) or 0 points (abnormal). The distribution of scores, as noted in the RBMT manual, are provided in

Table 9. Table 10 shows the results of the administration of the RBMT at the 8-month and 49-month evaluation.

Table 9

Standard Profile Scoring for the RBMT

Items	2 points	1 point	0 points
1st and 2nd Name	4	3	0-2
Belonging	4	3	0-2
Appointment	2	1	0
Pictures	10	9	0-8
Immediate route	5	4	0-3
Delayed route	5	4	0-3
Message	6	5	0-4
Orientation	9	8	0-7
Date	1	1 day out	2 or more days out
Faces	5	4	0-3
Immediate story	6 or more	4-5.5	3.5 or less
Delayed story	4 or more	2-3.5	1.5 or less

Table 10

Rivermead Behavioural Memory Test (RBMT) Results at 8-month and 49-month evaluation

Subtests	8-month	49-month
Overall Score (out of 12)	2	0

Immediate Story Recall (out of 21)	0	0
Delayed Story Recall (out of 21)	0	0
Immediate Route Recall (out of 5)	0	0
Delayed Route Recall (out of 5)	0	0
20 min predetermined task	Not able to complete	Not able to complete
20 min personal belongings	Yes with prompt	Not able to complete
Name	Unable to recall with cueing	Unable to recall with cueing

For the 8-month administration, the patient had an overall raw score of 2 out of 12. On Immediate story recall he achieved 3 of 21 items, and for the delayed story he achieved 0 out of 21 items. Immediate route recall he achieved 1 out of 5 items and achieved 0 items in the Delayed Route recall. He was not able to complete the 20 minute predetermined task and needed a prompt for the Personal Belongings subtest, but was unable to recall the name even with administrator cueing. At the 49-month evaluation, the patient was not able to navigate any of the subtests. It is interesting to note that for an assessment that looks at the ecological validity of functioning memory, the level of impairment seen at the 8-month assessment time is far different than what was seen on the WMS-III at the 3-month mark. There can be two possible scenarios: First, there could have been a large decline in functioning from the 3-month interval to the 8-month interval. Second, the WMS-III that is considered the standard for memory may potentially overestimate an individual's ability and thus fail to accurately gauge the level of functional impairment. It also brings to light the need to incorporate ecologically valid measures of daily functioning in neuropsychological assessment.

Fuld Object-Memory Evaluation (FOME). The Fuld Object-Memory Evaluation (FOME; Fuld, 1982) is another instrument used only once and thus we lack the capacity to compare data at different periods . FOME uses category-naming tasks for delayed recall of the originally presented stimuli to assess for verbal fluency, bilateral motor orientation, stereognosis, and aspects of memory in older adults such as long-term storage, retrieval and consistency of retrieval of information and learning in old. FOME is for age ranges 70 to 90 years and can be administered individually in 15 minutes. The test was developed with hundreds of geriatric individuals with all levels of functionality and was not biased against individuals with visual or auditory impairments. It is a measure that is sensitive to individuals with a dementia process. In FOME, 10 common objects in a bag are presented to determine whether the patient can identify objects by stereognosis. The patient is not told that memory of this event will be tested. Left and right hands are alternated systematically during the exercises (this provides information about the patient's left-right orientation). The patient names or describes each object and then pulls it out of the bag to see if the guess was accurate. After distracting the patient, by asking the patient to say words rapidly from a single category (rapid verbal retrieval), the patient is asked to recall the things from the bag. The patient is then offered four more chances to learn and recall them (store and retrieve); they are reminded of omitted items after each recall, with rapid verbal retrieval preventing rehearsal before each recall opportunity. Table 11 represents the results of FOME at the 19-month evaluation.

Table 11

Fuld Object Memory Test II Interference Results at 19-month evaluation

Subtests	Scores
Storage	38

Retrieval	22
Repeated Retrieval	10
Ineffective Reminder	14
Delay Recall	5
Recognition	5
Total	10

The results indicate that the patient's long-term working memory and recognition is impaired which is consistent with the results of the WMS-III.

Test of Memory Malingering (TOMM). The Test of Memory Malingering (TOMM; Tombaugh, 1996) is a 50-question visual memory recognition test to assess for malingering. Used on individuals aged 17 to 73, it takes 15 to 20 minutes the complete. The normative data was collected in two phases. In the first phase, 405 cognitively intact individuals ranging in age from 16 to 84 years were administered a preliminary version of the TOMM with revisions implemented based on the feedback data. In the second phase, the current two-choice version of the TOMM was administered to an additional sample of 70 cognitively intact patients ranging in age from 17 to 73 years, 63% of which were male and 37% female. For the clinical sample of the norming process, data was obtained from 158 inpatients and outpatients, including 13 patients with no cognitive impairment, 42 with a cognitive impairment, 21 with Aphasia, 45 Traumatic Brain Injury patients, and 47 Dementia patients. Validation studies performed on the above persons indicates that individuals who score in the severely impaired range on the standardized tests of learning and retention perform extremely well on the TOMM. This provides evidence that the TOMM is extraordinarily resistant to various types of severe cognitive impairment.

Support for the validity of the TOMM is also provided from studies with simulated and "at risk" malingerers. Results from the simulation study indicate that the TOMM discriminates between individuals who put forth good effort (high specificity) from those who deliberately fake responses (high sensitivity); it is a useful tool for detecting malingering. The patient's scores at the 3-month and 19-month evaluation are in Table 12 with 50 points as the maximum allowable amount in each category.

Table 12

Test of Memory and Malingering Results at 3-month & 19-month Evaluation

	3-month	19-month
Trial 1	46	42
Trial 2	50	49
Retention	48	50

The results of the TOMM indicate that the patient was not malingering or feigning memory problems at either of the assessment periods. That being said, the patient initially had more difficulty with memory at the 19-month evaluation compared to the 3-month evaluation, which would be consistent with the WMS-III data and additional time needed for memory consolidation.

Domain: Executive Functioning

Delis-Kaplan Executive Function System Color Word Interference. The Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan & Kramer, 2001) is designed to detect mild forms of executive function. It consists of nine tests that derive from pre-existing measures. The patient was administered the D-KEFS Color-Word Interference Test, a variant of

the Stroop procedure (Stroop, 1935) that can be traced back to the work of Cattell in the late 1800s (Mitrushina et al., 2005). Table 13 shows the patient's results on the D-KEFS Color Word Interference.

Table 13

D-KEFS C/W Interference Scale Score Results at 3 & 19-Month Evaluation

Subtests	3-month	19-month
Color	9	7
Word	12	10
Inhibition	1	5
Switch	1	1
Inhibition Error	1	1
Switch Error	1	1

A two-sample assuming equal variances *T*-test was performed and there was no significant difference between the scores for 3-month (M=4.166, SD=4.996) and 19-month (M=4.166, SD=3.18) conditions; t(10)=0.00, p = 1.00. Qualitatively it is noted that there was a decline in the functioning of 2 scale scores between the 3-month and 19-month evaluation for Color and Word subtests. On the Inhibition subtest, there is a noticeable improvement in scale scores yet with the subtests requiring more complex executive functioning, the patient is grossly impaired at both the 3-month and 19-month evaluations.

Wisconsin Card Sorting Test. The Wisconsin Card Sorting Test (WCST; Berg, 1948; Grant & Berg, 1948) assesses abstract reasoning skills and measures a complex range of executive functioning such as planning, organizing, abstract reasoning, concept formation,

cognitive set maintenance and shifting ability, and inhibiting impulsive responses (Lezak, 1995; Lezak, Howieson, & Loring, 2004; Spreen & Strauss, 1998). The WCST is used with individuals aged 5 to 89 years and approximate time for administration is 20 to 30 minutes. Standardization data (Heaton, Chelune, Talley, Kay, & Curtis, 1993) provide norms for individuals aged 6 years and 5 months to 89 years. The norms were derived from 899 normal patients from six samples. The WCST consists of four stimulus cards placed in front of the patient. The first with a red triangle, the second with two green stars, the third with three yellow crosses, and the fourth with four blue circles on them. The patient is given two packs of 64 response cards and is asked by the examiner to match each of the cards in the decks to one of the four key cards. The patient is told each time a card is placed down whether they are right or wrong. No warning is given for a change in the sorting rules. There is no time limit for this test (Strauss et al., 2006).

In brief, the various scores are as follows: Number of Categories Completed is the number of sequences of 10 consecutive correct matches (max=6). Trials to Complete First Category alludes to its namesake. The Perseverative Responses and Perseverative Errors Category alludes to the concentration of perseverative errors in relation to overall test performance (the number of trials given) multiplied by 100. Failure to Maintain Set refers to when a patient makes five or more consecutive correct matches, but then makes an error before successfully completing the category. Percent Conceptual Level Responses refers to the consecutive correct responses occurring in runs of three. Learning to Learn is the patient's average change in conceptual efficiency across the successive stages (categories) based on percent error difference scores for each consecutive pair of adjacent categories. Table 14 illustrates the patient's performance on the WCST at the 3-month and 19-month evaluation using age and education demographically corrected T-scores.

Table 14

Wisconsin Card Sorting Test (WCST) Results at 3-month and 19-month Evaluation with Age and Education Demographically Corrected T-scores

	3-month *T*-scores	19-month *T*-scores
Trials Administered	* --	* --
Total Correct	* --	* --
Total Errors	33	40
Percent Errors	35	41
Perseverative Responses	39	39
Percent Perseverative Responses	39	41
Perseverative Errors	37	41
Percent Perseverative Responses	38	42
Non-perseverative Errors	33	41
Percent Non-perseverative Errors	34	43
Conceptual Level Responses	* --	* --
Percent Conceptual Level Responses	33	38
Categories Completed	* --	* --
Trials to Complete 1st Category	* --	* --
Failure to Maintain Set	* --	* --
Learning to Learn	* --	* --

* No data is available

The patient was not able to complete any of the categories at the 3-month nor the 19-month evaluations.

A paired-samples *t*-test assuming was conducted on the available categories of the WCST and there was a significant difference at the p<0.001between the scores for the 3-month (M=35.66, SD=2.598) and 19-month (M=40.66, SD=1.5) and condition; t(16)=- -5.000, p = 0.000.

Table 15

Results of t-test and Descriptive Statistics for Changes in WCST T-Score Results from 3-Month Evaluation and 19-Month Evaluation

	3-month evaluation		19-month evaluation		99.9% CI		
Outcome	M	SD	M	SD		t	df
	35.66	2.598	40.66	1.5	[-5.000, -9.015]	-5.000*	16

* p < .001.

Qualitatively, the inability to make categories in WCST and corresponding poor performance is consistent with the patient's difficulty in executive function as seen on the D-KEFS Color-Word Interference subtest.

Behavioral Assessment of Dysexecutive Syndrome. The Behavioral Assessment of Dysexecutive Syndrome (BADS; Wilson, Alderman, Burgess, & Emslie, 1996) is another measure that assesses executive functioning. BADS was developed to evaluate the executive functioning (EF) of an individual with tasks that resemble daily life to areas such as inhibitory control, problem-solving, judgment, abstract thought, planning, organizing, and monitoring

behavior. BADS can be administered to individuals aged 16 to 87 years in approximately 30 minutes (Strauss et al., 2006).

BADS consists of six subtests with the associated areas of EF evaluation as follows: Rule Shift Cards tests inhibitory control and ability to switch focus. Action Program tests the ability for the patient to approach a problem and develop an effective solution that is congruent with the perimeters of the exercise. Key Search tests the ability to formulate an effective strategy using implicit situational information. Temporal Judgment involves evaluating abstract judgment and thinking regarding four common events. Zoo Map tests formulation and execution of a plan limited by certain rules. Six Elements tests the patient's ability to plan and organize the task and then manage the construct of time. BADS also incorporates the BADS Dysexecutive Questionnaire (DEX) that is distributed to the patient and caregivers for self-rating. It consists of 20 questions regarding patient effectiveness with daily living. There is a maximum score of 80 points on each questionnaire. Behavioral Assessment of the Dysexecutive Syndrome was effective in detecting executive function deficits in mild Alzheimer's disease patients, particularly the task-switching, time-monitoring, and rule-shift subtests (Bertolucci, Brucki, Bueno, & Canali, 2011). A recent study by Espinosa et al. (2009) concluded that BADS was an appropriate means of detecting executive deficits in the early Alzheimer Dementia (AD; Espinosa et al., 2009). Table 16 represents the patient's profile on the BADS at the 49-month evaluation.

Table 16

Behavioral Assessment of the Dysexecutive Syndrome (BADS) scores on the 49-month evaluation

Category	49-month
Profile Total	0

Action Program	0
Key Search	0
Modified Six Elements	Not able to complete
Rule Shift Cards	-1
Zoo Map	0
Temporal Judgment	1

Significantly, with the Rule Shift cards exercise, the patient had more than 20 total errors leading to a profile score of zero. In addition, he took much longer than 67 seconds to complete the test and, according to the standardization for the test, that leads to the subtraction of 1 from the profile score, leaving the patient with a profile score of negative one (-1). His overall score was 0 which places him in the "profoundly impaired" category.

Domain: Sensorimotor

Finger Tapping Test. Originally known as the Finger Oscillation Test (FOT; Halstead, 1947), the Finger Tapping Test (FTT) is used to measure motor speed and motor control (Mitrushina, et al., 2005) in individuals aged 5 to 85 years. The FTT (Reitan, 1979) uses an adapted tapper and counter. The patient is instructed to place the hand to be assessed palm down with fingers extended and the index finger placed on the key. The patient is instructed to tap as quickly as possible for 10 seconds using the index finger of the dominant hand. This procedure is conducted for five consecutive trials within a five-point range with each hand (Reitan & Wolfson, 1985) and then the process is replicated with the non-dominant hand (Strauss et al., 2006). Age, gender, education, and ethnicity can influence the results of the FTT and because of

Heaton, Miller, Taylor, & Grant (2004), normative data is the recommended structure for data evaluation.

At the 3-month mark, the patient's dominant hand had a scale score of 6 with a descriptive classification of mildly impaired. At the 19-month mark, the dominant hand had a scale score of 12 and with a descriptive classification of average. For the non-dominant hand, the 3-month scale score was 9 with a descriptive classification of average, while at the 19-month evaluation the scale score was 10 with a descriptive classification of average. The left hemisphere motor cortex controls the right side of the body. This was the area impacted during the motor vehicle incident, which may account for the decreased functioning noted in the dominant hand at the 3-month evaluation. The rate of change from the 3-month evaluation to the 19-month evaluation is 0.375 scale scores per month in the dominant hand and 0.0625 scale scores per month in the non-dominant hand. As can be seen, there is a marked improvement in fine motor skills of the dominant hand over time which is a different trajectory compared to other areas of functioning. A paired-samples *t*-test assuming was conducted and there was no significant difference between the scores for the 3-month (M=7.5, SD=2.12) and 19-month (M=11, SD=1.41) evaluation; t(2)=- 1.941, p = 0.192.

Domain: Attention

Trail Making Test. The Trail Making Test (TMT; Reitan & Wolfson, 1985) was originally created in 1938 as Partington's pathways (Partington & Leiter, 1949) with a divided attention test that was assimilated into the Army Individual Test Battery (1944), and was then included in the Halstead-Reitan Battery (Reitan & Wolfson, 1985). The TMT measures attention, mental flexibility, and fine motor speed. The TMT provides feedback on executive functions, visual scanning, speed, mental flexibility, and has attained "considerable popularity due to its

high sensitivity to the presence of cognitive impairments" (Mitrushina et al., 2005, p. 59) and processes (Lezak, 1995; Spreen & Strauss, 1998). The adult version of the TMT is for persons aged 15 to 89 years. Administration time for the TMT is 5 to 10 minutes. Scoring for the TMT is expressed in terms of the times in seconds required for completion of each of the two parts the test.

The TMT is split into two parts: TMT-A and TMT-B. The TMT-A requires the patient to sequentially draw lines connecting 25 numbers on a sheet of paper as quickly as possible. TMT-B requires the patient to alternate between ascending numbers and letters in alphabetical order (e.g., 1, A, 2, B, 3, C, etc) as quickly as possible. The score on TMT-A and TMT-B represents the amount of time it took for the patient to complete the task. Scores on the TMT are influenced by age, education, and intelligence (Spreen & Strauss, 1998). The TMT is sensitive to closed brain injuries (desRosiers & Kavanagh, 1987) with an escalation in completion time noted with increasing severity of the head injury (Dikmen, Ross, Machamer, & Temkin, 1995; Iverson, Lange, Green &Franzen, 2002; Lange, Iverson, Zakrzewski, Ethel-King, &Franzen, 2005; Martin, Hoffman, &Donders, 2003). This is potentially attributable to diffuse axonal injury (Felmingham, Baguley, & Green, 2004).

The patient was administered the TMT at the 3-month and 19-month post-MVA assessment. The results of the patient's performance were based on *The Revised Comprehensive Norms for an Expanded Halstead-Reitan Battery: Demographically Adjusted Neuropsychological Norms for African American and Caucasian Adults* (Heaton et al., 2004). At the 3-month evaluation, TMT-A had a scaled score of 7 and the patient fell within the descriptive classification as "average." The TMT-B had a scale score of five. At the 19-month interval, the patient's TMT-A was a scaled score of 5 and the TMT-B was a scale score of 3. A paired-

samples *t*-test assuming was conducted and there was no significant difference between the scores for 3-month (M=6, SD=1.41) and 19-month (M=4, SD=1.41) evaluations; t(2)=1.414, p = 0.293.

Qualitatively, the patient's ability to set shift between numbers and letters declined by 2 scale scores between the two evaluations for both the TMT-A and the TMT-B, which shows a linear decrease in not just simple executive functioning but also the decline in set-shifting ability.

Domain: Language

The Controlled Oral Word Association Test. The Controlled Oral Word Association Test (COWAT; Spreen & Benton, 1969, 1977) is also known as the verbal fluency test. It encompasses Word Fluency, Letter Fluency, FAS-Test, Category Fluency, Phonemic Fluency, Semantic Fluency, Controlled Verbal Fluency, and the Thurstone Word Fluency Test (Strauss et al., 2006, p. 499). It was administered to assess verbal association fluency, which is the spontaneous verbalization of words under certain categories. It is the primary procedure used to assess verbal fluency (Iverson, Franzen, & Lovell, 1999; Rabin, Barr, & Burton, 2005; Retzlaff, Butler, & Vanderploeg, 1992;), and is sensitive to indicators of brain dysfunction (Benton, Hamsher, & Sivan, 1994; Lezak et al., 2004; Miceli, Caltagirone, Gainotti, Masullo, & Silveri, 1981; Ross, 2003; Spreen & Stauss, 1998; Strauss et al., 2006) such as traumatic brain injury (Henry & Crawford, 2004; Iverson et al., 1999), lesions to the frontal cortex (Baldo & Shimamura, 1998; Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001), and Alzheimer's disease (Chertkow & Bub, 1990; Crawford & Phillip, 2004; Margolin, Pate, Friedrich, & Elia, 1990). The administration time is five to ten minutes. This measure requires the generation of words based on the initial letter. The patient was administered the COWAT at the 3-month and 19-month evaluation and the scale scores are found in Table 17.

Table 17

Controlled Oral Word Association Test (COWAT) Scale Score Results at 3-month and 19-month Evaluation

Subtests	3-month Scale Scores	19-month Scale Scores
CFL	11	8
Animals	12	6

The rate of scale score change per month between the 3-month and 19-month evaluations was -0.1875 for the CFL and -0.375 for the Animals. A paired-samples *t*-test assuming was conducted to compare the Controlled Oral Word Association and there was a significant difference between the scores for 3-month (M=77.5, SD=40.5) and the 19-month (M=18.5, SD=144.5) conditions; $t(2)=6.135$, $p = 0.026$.

Table 18

Results of t-test and Descriptive Statistics for Changes in Controlled Oral Word Association Percentage from 3-month Evaluation and 19-Month Evaluation.

	3-month evaluation		19-month evaluation		95% CI		
Outcome	M	SD	M	SD		t	df
	77.5	40.5	18.5	144.5	[17.618,100.382]	6.135*	2

* $p < .05$.

Qualitatively, the patient had a significant decline in both subtests between the 3-month and 19-month evaluation that corresponded to the increase in word finding difficulties as well as abstract thinking processes.

Wide Range Achievement Test. The Wide Range Achievement Test (WRAT; Wilkinson, 1993) was introduced in 1936 and has gone through five revisions that have included

simple re-norms involving the use of Rasch analysis, scaling, and revised normative data (Reid, 1986). The content validity, standardization approach, and reliability has been contested (Reynolds, 1986). Compared to the COWAT, which requires abstract thinking and verbal production of words, the WRAT accesses memory functions that have been well-learned through formal education. Table 19 shows the patient's performance at the 19-month evaluation.

Table 19

Wide Range Achievement Test (WRAT) Tan Form Results at 19-Month Evaluation

Subtests	Standard Scores	Percentile	Grade Equivalent
Reading	115	84	PHS
Spelling	110	75	PHS
Arithmetic	93	32	5

PHS= Post High School

As can be seen, from the results of the 19-month evaluation, the patient presents at a post-high school level in reading and spelling, with Reading at the 84th percentile and Spelling at the 75th percentile. The arithmetic score, however, is at the 32nd percentile - a 5th-grade equivalent. Given the patient's background in engineering, with its high emphasis on arithmetic, the score is markedly low for his level of education.

Boston Diagnostic Aphasia Examination (BDAE). The Boston Diagnostic Aphasia Evaluation (BDAE; Goodglass, & Kaplan, 1972) was revised in 1983 (BDAE-2; Goodglass & Kaplan, 1983) and in 2001 (BDAE-3; Goodglass, Kaplan, & Barresi, 2001a, 2001b). BDAE is for individuals 16 years and older and administration time is approximately 40 to 60 minutes for the short form version, and approximately 90 minutes for the long version. BDAE examines traditional aphasia syndromes, conversational speech and auditory comprehension, oral expression, reading, writing, praxis, constructional ability, calculations, finger gnosis, and

directional orientation (Strauss et al., 2006). This individual was administered the BDAE at the 3-month assessment and at the 19-month assessment (see Table 20).

Table 20

Boston Diagnostic Aphasia Examination 3rd Edition at 3-month and 19-month

	3-month	19-month
Raw	12	8
Errors	0	4
Inference	1	0
Percentile		< 1

Given that there are many subtests in the BDAE, and the chart did not specify which subtests were administered, it is impossible to know from where the raw scores were derived. The chart does note that, at the 19-month evaluation, the patient's BDAE score was ranked at the less than one percent range. Although it was not stated, it can be assumed that his percentile rank at the 3-month evaluation was slightly higher.

Boston Naming Test - Second Edition. The Boston Naming Test (BNT; Kaplan, Goodglass, & Weintraub, 1978) initially involved the administration of 85 drawings, but was later modified to 60 drawings (Kaplan, Goodglass, & Weintraub, 1983) with the same presentation model. The Boston Naming Test, 2nd Edition (BNT-2; Kaplan, Goodglass, & Weintraub, 2001) includes the 60 drawings and "a short 15-item version as well as a multiple-choice version" (Strauss et al., 2006, p. 901). The administration time is 10 to 20 minutes and can be administered to individuals 5 to 13 years of age as well as those individuals 18 years and older. The BNT taps into visual object naming processes and the patient's results are in Table 21.

Table 21

Boston Naming Test Results at 3-month & 19-month Evaluation

	3-month	19-month
T scores	49	42
Descriptive Classification	Average	Low average
Percentile	47%	21%

For this individual, there was a 7-point decline in T-scores between the 3-month and 19-month evaluation, shifting him from 47% to 21% in comparison to other individuals in his age bracket.

Domain: Visual Spatial

Rey-Osterrieth Complex Figure test (ROCF). The Rey-Osterrieth Complex Figure Test (ROCF; Osterrieth, 1944; Rey, 1941) assesses visual-spatial ability, visual memory, planning and problem-solving strategies. The administration of this test involves copy, immediate recall, and delayed recall drawing trials. The patient initially copies the figure onto a blank sheet of paper. The stimulus is then removed and, after a 10 to 15 minute delay, the patient is asked to recreate the figure. The RCFT is reported to have a high reliability ranging from .93 to .97 (Deckersbach et al., 2000) and is sensitive to "non-dominant hemisphere functioning and right temporoparietal area integrity in particular" (Mitrushina et al., 2005, p. 249).

The patient was administered the ROCF at the 3-month evaluation and again at the 19-month evaluation. For both the 3-month and the 19-month evaluation, the patient's scores were the same (Copy= 90%, 30 minute copy= 11% or approximately a scaled score = 6). This shows that there was not a decrease in visuospatial ability between the assessments, yet visuospatial memory retention was impaired at the 3-month evaluation. His performance is consistent with what his scores were on the WMS-III for Visual Reproduction Delayed at the 3-month and 19-

month evaluation where he received a scale score of five which is only one scaled score difference than the percentage equivalent on the ROCF.

Domain: Personality

Minnesota Multiphasic Personality Inventory-2. The Minnesota Multiphasic Personality Inventory-2 (MMPI-2; Butcher, Dahlstrom, Graham, Tellegen, & Kaemmer, 1989) is a self-reporting test normed on 1138 adult males and 1462 adult females and collected in seven locations from around the United States (Graham, 2006). The MMPI-2 contains 567 true or false items and takes 60-90 minutes to administer to individuals 18 years and older who have at least a fifth grade Lexile average reading level or 4.6 grade Flesch-Kincaid reading level.

The MMPI's test-rest reliability is recorded as .50 to .80. The administration of the MMPI-2 is either paper and pencil, online, computer, or CD and takes approximately 60 minutes to administer. The MMPI-2 is available in English, Spanish or French for Canada. Scoring options available for the MMPI-2 are the Q-global Scoring and Reporting, Q Local Software, Mail-in Scoring Service, or Hand Scoring. Report options available for the MMPI-2 include the Extended Score Reports, Adult Clinical Interpretive Reports, Forensic Settings Reports, and Personnel Interpretation and Adjustment Rating Reports. The initial publication date for the MMPI-2 was 1989, but it was revised in 2001, and then updated again in 2003 and 2009. It is published by the University of Minnesota Press.

The MMPI-2 is composed of Validity Scales and Clinical Scales. The MMPI-2 Validity scales consist of three subscales: L scale, F scale, and K scale. The L scale (Lie) assesses patients' attempts to present themselves in a favorable light. The F scale (Infrequency) assesses any atypical ways of responding. The K scale (Correction) assesses the patients' attempts to expand or mitigate problems. The Clinical Scales consist of ten sub-scales. The H scale

(Hypochondriasis) assesses an individual's perception of the status of health. The D Scale (Depression) measures symptoms of depression. The Hy Scale (Hysteria) measures an individual's somatic concerns and tendency to deny problems. The Pd Scale (Psychopathic Deviate) measures rebellion and sense of alienation. The Mf Scale (Masculinity-Femininity) measures interest and attitudes related to socially conventional gender stereotypes. The Pa Scale (Paranoia) measures ideas of being misunderstood, persecuted or treated unfairly. The Pt Scale (Psychasthenia) measures an individual's proclivity to ruminate and worry. The Sc Scale (Schizophrenia) measures an individual's level of disturbed thinking, mood, and behavior. The Ma Scale (Hypomania) measures an individual's level of activity and excitability. The Si Scale (Social Introversion) measures the tendency of the patient to withdraw from social engagement and tend towards introversion. A *T*-score of 60 or above is considered clinically significant. The patient's scores at the 3-month and 19-month evaluations are in Table 22.

Table 22

Minnesota Multiphasic Personality Inventory-2 (MMPI-2) T-score Results at 3-month and 19-Month Evaluation

Scales	3-month	19-month
L	65	43
F	42	51
K	54	47
Hs	54	39
D	68	42
Hy	57	45
Pd	54	46
Mf	56	48

Pa	49	53
Pt	61	49
Sc	58	51
Ma	49	49
Si	62	51

A paired-samples *t*-test assuming equal variances was conducted to compare the MMPI-2 and there was a significant difference between the scores for 3-month (M=56.07, SD=7.05) and the 19-month (M=47.23, SD=4.106) conditions; t(24)=3.908, p = 0.001. For this individual, there was an interesting change in some of the scales. For the L scale, he received a T-score of 65 at the 3-month timeframe and then it dropped to 43 at the 19-month evaluation. Similarly, the D scale was initially elevated (T score = 68) and then decreased to 42 by the 19-month evaluation. According to a chart note from the first evaluation at the 3-month timeframe, the patient was reported as being pleasant and the patient sees himself as having no personality changes. His wife, on the other hand, indicates that there were significant personality changes including flat affect.

The Scales of Independent Behavior Revised. The Scales of Independent Behavior (SIB; Bruininks, 1984) and The Scales of Independent-Revised (SIB-R; Bruininks, Woodcock, Weatherman, & Hill, 1996) can be self-administered or administered by interview to assess functional independence and behavioral problems for individuals ranging from infancy to adulthood. The SIB-R consists of 259 items organized into 14 subscales that are, in turn, in four behavioral clusters: Motor, Social Interaction and Communication, Personal Living, and Community Living.

The SIB was originally normed on 1,764 individuals based upon the characteristics of the 1980 U.S. Census. For the SIB-R, a supplemental sample of 418 individuals based upon 1990 U.S. Census data was incorporated into the norming process for a total normative sample size of 2,182 (Strauss et al., 2006). The administration time is approximately one hour.

The Scales of Independent Behavior-Revised (SIB-R; Bruininks et al.,1996) is a norm-referenced assessment of 14 areas of adaptive behavior, constructing the four adaptive domains of motor skills, social interaction and communication, personal living, and community living. The eight areas of maladaptive behavior construct the three maladaptive domains of internalized, asocial, and externalized functioning and was standardized on 2,182 individuals throughout the United States. The structured interview or checklist administration covers functional independence and adaptive functioning in home, school, employment, and community settings. The SIB-R can be administered to individuals with age ranges from infancy to 80 years of age and can be administered in 45 to 60 minutes. Reliability is ensured through internal consistency, high test-retest, and comparison of independent raters. The patient's results on the SIB-R are seen in Table 23.

Table 23

Scales of Independent Behavior-Revised (SIB-R) Domain Percentiles at 49-Month Assessment

	%iles
Motor Skills	98
Social Interaction and Communication Skills	1
Personal Living Skills	96
Community Living Skills	3
Broad Independence (Full Scale)	<0.1

At the 49-month mark, this patient's Broad Independence ability was at the <0.1 percentile. The Broad Independence ability is constructed from four subcategories: Motor skills, Social Interaction and Communication skills, Personal Living Skills, and Community Living Skills. In this assessment, the patient was at the 98th percentile for Motor Skills and 96th percentile for Personal Living Skills. For behaviors that involve verbal communication and higher levels of executive functioning, the patient had great difficulty. He was at the first percentile for Social Interaction and Communication Skills and third percentile for Community Living Skills.

Interventions. The patient's available medical records contain little information on interventions. For the 3-month evaluation, there are indications that, it was recommended that he would benefit from individual and group neurorehabilitation along with referrals for speech therapy and vocational assistance. According to the medical records, this individual did engage in the neurorehabilitation process and saw improvement, but medical records indicate that the rehabilitation process was discontinued within a short time frame.

Discussion

The historical data that is presented in this dissertation provides crude normed-based understandings of how one individual functioned at various points in time over the subsequent 49 months after a motor vehicular collision. The hypothesis was that his decline might be a sequela of CTE. Although the above data is derived from normed assessment instruments, there are inherent strengths and limitationsto those instruments, and I posit that there are many phenomenological dimensions to this individual for which there are no existing standardized measures, nor should there be. The available data in this dissertation is a crude estimation to the complexity of this individual and the scores should not be used in a reductionist manner so as to force him or his life into one defined by numbers.

The author has found it useful to consider the data as the equivalent of major brushstrokes on an impressionist painting. The color and hue of the strokes change over time and this alters the composite picture, and there are many strokes that were not or could not be captured. This case study reveals that there are statistically significant changes in functioning that occurred between neuropsychological evaluations. The statistically marked changes are noted in multiple domains.

First, in the area of intelligence, there are the WAIS-III VIQ and PIQ composite scores. Here, the change noted between the 19-month and 49-month evaluation is significant at the $p<.05$ level: 19-month ($M=87$, $SD=3.535$) and 49-month ($M=87$, $SD=7.071$) conditions; $t(2)=5.473$, $p = 0.05$, but this was not true for the 3-month and 19-month VIQ and PIQ composite scores. When the WAIS-III was viewed at the subtest level there was a significant difference at the level of $p <.05$ between the 3-month ($M=-10.272$, $SD=2.284$) evaluation and 19-month ($M=7.909$, $SD=1.037$) evaluation; $t(20)=2.182$, $p = 0.041$. The significance was even stronger ($p <.001$) for the scaled scores for 19-month ($M=7.909$, $SD=2.773$) and 49-month ($M=3$, $SD=3.16$) conditions; $t(20)=3.871$, $p = .001$.

Second, there is the domain of memory. The scaled score results for the WMS-III Logical Memory Immediate and Delayed demonstrated a significant difference when comparing the 3-month ($M=6$, $SD=0$) and 19-month ($M=3.5$, $SD=0.707$) conditions; $t(2)=5.000$, $p = 0.05$ as well as the between the 19-month ($M=3.5$, $SD=0.707$) and 49-month ($M=1$, $SD=0$) conditions; $t(2)=5.000$, $p = .05$. For EF, there was a significant difference $p < .001$for the categories on the WCST between the 3-month ($M=35.66$, $SD=2.598$) and 19-month ($M=40.66$, $SD=1.5$) evaluation; $t(16)=- -5.000$, $p = 0.000$.

The third area is language. For language, a paired-samples *t*-test assuming was conducted to compare the Controlled Oral Word Association, and there was a significant difference $p < .05$ between the scores for 3-month (M=77.5, SD=40.5) and the 19-month (M=18.5, SD=144.5) condition; $t(2)=6.135$, $p = 0.026$.

Overall, through a qualitative lens, there was a general decline in the patient's cognitive and emotional functioning over the years since the TBI. Although it may not be statistically significant, as was described before, there are areas in which the patient had an obvious decline over time. At the 49-month evaluation, there was a decline in all areas of functioning to the point where he was impaired except for those aspects firmly encoded in his memory prior to the accident.

This dissertation presented a case study of a geriatric individual's longitudinal change in neurocognitive functioning following what appeared to be a mild TBI, with subsequent sequelae of potentially CTE. The investigation led to several important considerations. First, it highlights the vulnerability of geriatric individuals, as compared to younger individuals, to substantial brain injury at lower mechanism threshold for force. Consequently, it is important for clinicians to have an elevated index of suspicion, and to inquire and document even seemingly innocuous falls. As the research indicates, there is a residual and potentially layering effect of the inflammatory process that may accentuate a dementia process following a TBI depending on the epigenetics of the individual.

This gives rise to a second point: genetic biomarker analysis in neuropsychology can be used to provide more data regarding the individual's statistical susceptibility to the development of the chronic traumatic encephalopathy dementia process. At the time of this research, this approach is not being implemented even though it may help to inform the level and

aggressiveness of neurocognitive rehabilitation and prevention interventions for individuals at a higher risk. Although science is not there yet, someday there might exist technology to turn off those genes that lead to the development of tau and amyloid plaques that are endemic to the CTE dementia process.

Third, this case highlights the need for repetitive neuropsychological evaluations in elderly individuals to monitor progress and rates of deterioration to provide more specified and effective interventions. This need is potentially attributable to the blatant ageism and classism that is endemic to western capitalist culture, as well as vestigial and inaccurate cultural constructs of aging. With the baby boomer generation entering the geriatric phase of life, this is the first time in history where a large cohort effect can be explored and monitored to inform the process of aging for future cohorts.

Fourth, the constructs used to assess geriatric individuals after a TBI may not be effective in picking up the subtle shifts in functioning until the pathology has reached a tipping point of deterioration. It appears that abstract reasoning skills and EF skills are early harbingers of pathophysiological processes. The EF assessment is the proverbial and literal "canary" in the mine of neuropathological processes and can be invaluable for diagnostic ability.

Fifth, given the chronic and prolonged deterioration in this individual, combined with the knowledge of a protracted neuroinflammatory effect following a TBI, the research shows that at least in geriatric individuals (and potentially individuals of a younger cohort), prolonged neurocognitive rehabilitation should be instigated as the inflammatory reaction and the subsequent deterioration is prolonged.

Sixth, this case highlights the possibility of using the changes over time in neuropsychological assessment results to better define the neuropathological process. Currently,

diagnosis is made up of a constellation of data points at a single point in time. But what if there are patterns of change over time that are specific to the various types of neuropathological processes and can be used as an adjunctive diagnostic tool? As this is a single case, it is impossible to prove this hypothesis at this time.

Although it does not currently exist and the logistics are not yet clear, it may be potentially advantageous to set up a centralized dataset where private clinicians and medical systems can input the scaled scores and *T*-scores of collected neuropsychological evaluations, with the understanding of a re-evaluation in one year. Based upon a larger data set, it would be possible to provide further statistical analysis to see if changes over time are useful as a more precise diagnostic tool for the geriatric population.

Implications

This investigation's results have implications for current approaches to treatment of geriatric individuals who have incurred a possible TBI. First, it highlights the pronounced vulnerability of geriatric individuals to experience substantial brain injury and subsequent dysfunction with forces that may not, at first glance, be regarded as sufficient to cause brain injury. There needs to be further research and evaluation regarding the susceptibility of the aging brain to mechanical forces. This may potentially increase the index of suspicion of professionals, from first line responders to physicians, so as to provide access to neurorehabilitation services and protocols. Additionally, a re-evaluation of the neurorehabilitation interventions and duration should also be reconsidered. There is research that already supports the notion of a prolonged inflammatory process that can be seen in cerebral spinal fluid biomarkers months after an initial head trauma, and is visible upon post-mortem immunohistological examination. It is also known that due to the polypharmacological approach to medicine and frequent medical co-morbidities,

there is a higher vulnerability to falls and trauma in the older population. Given these two factors, a more aggressive and prolonged approach to neurorehabilitation should be an area of future research and may provide for more optimal support for geriatric individuals to enable them to stay functional.

Secondly, this dissertation encourages the reconsideration of this paradigm and suggests that the technology of neuropsychology be used as a platform for longitudinal tracking of an individual's functioning. This is advantageous for many different reasons. For one, neuropsychology can detect cognitive changes that may not yet be perceptible through other modes of observation. It is possible that with early diagnosis of cognitive changes there is a chance to initiate interventions that may potentially slow down the cognitive deterioration, allow for protracted levels of functioning, and hopefully lead to a better quality of life for individuals, their families and communities. A second reason revolves around the construct of longitudinal neuropsychological tracking which is currently not a standard care of practice in the health care system. This is a glaring discrepancy and ironic given health care's predisposition for longitudinal tracking of medical conditions such as coronary artery disease and cancer. By shifting this perspective, it would allow for a much more congruent and supportive approach to a patient's healthcare and hopefully provide better overall results. In addition, the longitudinal approach, if combined with the ability to centralize the de-identified data, will allow researchers to better understand neuropsychological changes in population cohorts over time. Although we lack the necessary evidence at this time, this author contends that certain slower evincing neuropathologies will demonstrate different degrees of change over time in different domains. If there is a way to understand these changes and the associated nuanced pattern, it could facilitate earlier diagnosis and interventions that may be conducive to increased functionality and quality

of life. Third, a centralized data store of neuropsychological data may provide researchers a better understanding of the aging process from an anthropological perspective, and may potentially lead to societal and governmental policy changes advantageous to cohorts of individuals as they age.

Fourth, in a zeitgeist where quantitative data and randomized control trials are given more weight and importance by clinicians and institutions, the single case design is not easily located in neuropsychology journals. Ironically, the examination of single cases was the foundation upon which Freud disseminated his ideas and approaches that have now become codified within psychology. In quantitative approaches, the lived experience of the individual and the individual's narrative is removed and replaced with numbers, arguably leading to an oversimplified view of human functioning. The single case design methodology for this dissertation used historical data to tell a qualitative and quantitative narrative for which no other methodologies are available. The approach to this single case design had to be retro-engineered from Kazdin's constructs as there is no professionally accepted methodology at this time for examining and adequately conveying quantitative longitudinal data and qualitative historical neuropsychological and clinical information. An additional area of future research would involve expanding the methodologies to encapsulate and properly convey outlier clinical scenarios such as the ones discussed in this dissertation.

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Appendix A

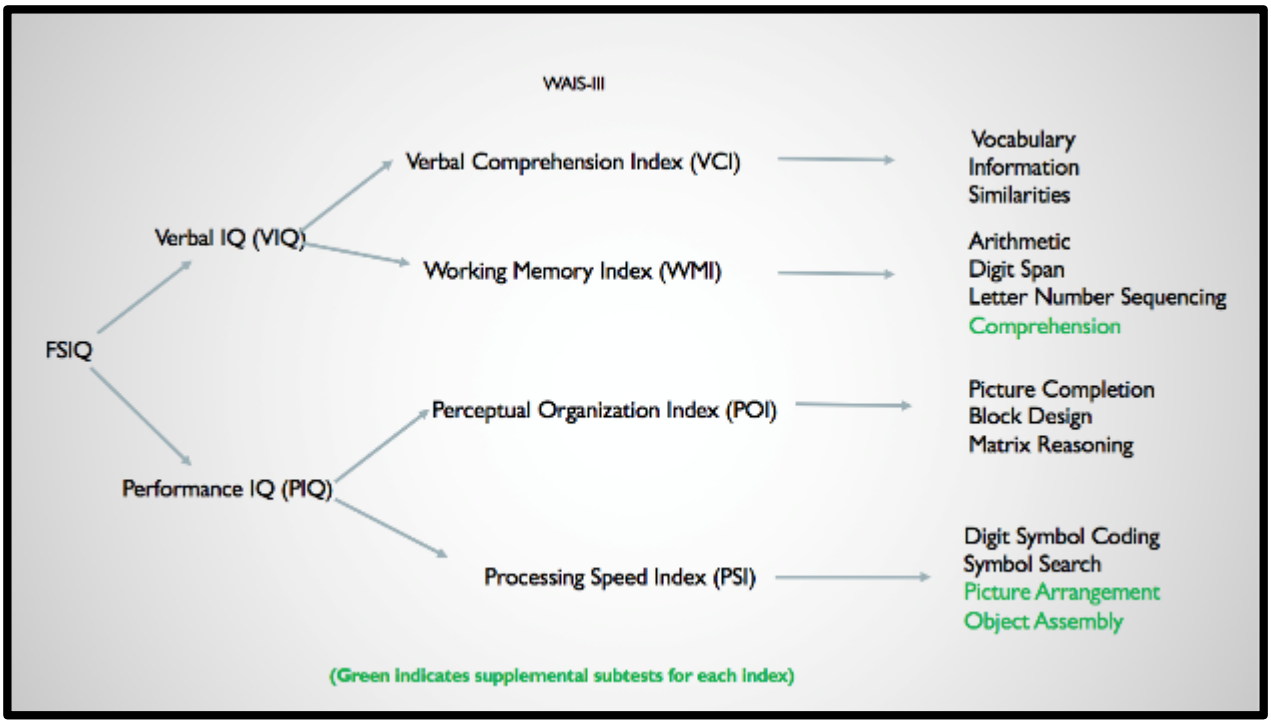
Alphabetical Listing of Chart of Psychological Assessments

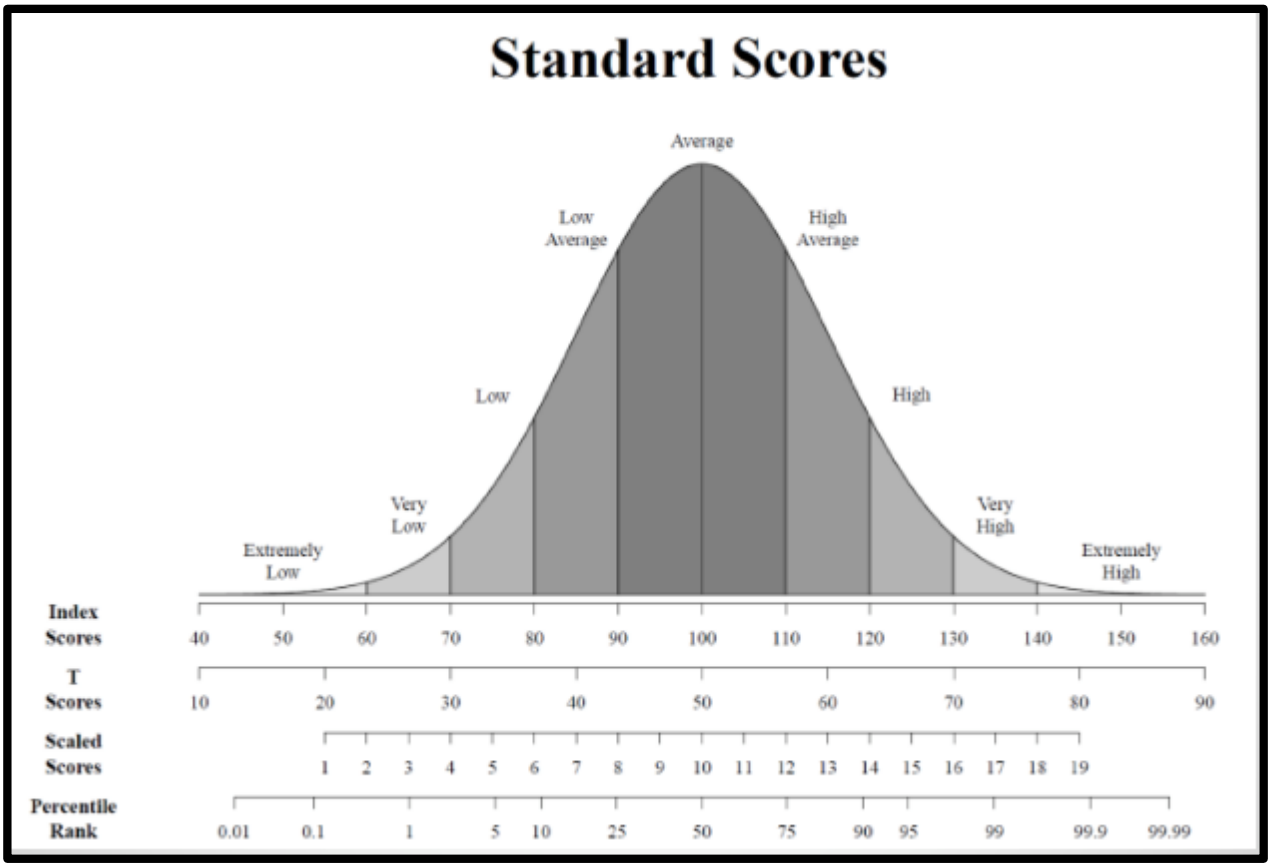
Alphabetical Listing of Chart of Psychological Assessments Administered at 3-month, 8-month, 19-month, and 49-month evaluation

Assessment Instruments	3-month	8-month	19-month	49-month
Behavioural Assessment of Dysexecutive Syndrome (BADS)				x
Boston Diagnostic Aphasia Examination- Third Edition (BDAE-3)	x		x	
Boston Naming Test (BNT)	x		x	
Controlled Oral Word Association Test (COWAT)	x		x	
Delis-Kaplan Executive Function System-Color/Word Interference (DKEFS-C/W)	x		x	
Finger Tapping Test (FTT)	x		x	
Fuld Object Memory Evaluation (FOME			x	
Minnesota Multiphasic Personality Inventory – Second Edition (MMPI-2)	x		x	
Rey Osterrieth Complex Figure (ROCF) and 30-minute delay	x		x	
Rivermead Behavioural Memory Test (RBMT)		x		x
Scales of Independent Behavior- Revised (SIB-R)				x
Test of Memory Malingering (TOMM)	x		x	
Trail Making Test Part A and B (TMT-A, TMT-B)	x		x	
Wechsler Adult Intelligence Scale- Third Edition (WAIS-III)	x		x	x
Wechsler Memory Scale- Third Edition (WMS-III)	x		x	x
Wide Range Achievement Test (WRAT)			x	
Wisconsin Card Sorting Test (WCST)	x		x	

Appendix B

Charts of Associated Data Graphs


WAIS-III
FSIQ
Verbal IQ (VIQ)
Performance IQ (PIQ)
Verbal Comprehension Index (VCI)
Working Memory Index (WMI)
Perceptual Organization Index (POI)
Processing Speed Index (PSI)
Vocabulary
Information
Similarities
Arithmetic
Digit Span
Letter Number Sequencing
Comprehension
Picture Completion
Block Design
Matrix Reasoning
Digit Symbol Coding
Symbol Search
Picture Arrangement
Object Assembly
(Green indicates supplemental subtests for each Index)


Standard Scores
Average
Low Average
High Average
Low
High
Very Low
Very High
Extremely Low
Extremely High
Index Scores
40 50 60 70 80 90 100 110 120 130 140 150 160
T Scores
10 20 30 40 50 60 70 80 90
Scaled Scores
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Percentile Rank
0.01 0.1 1 5 10 25 50 75 90 95 99 99.9 99.99

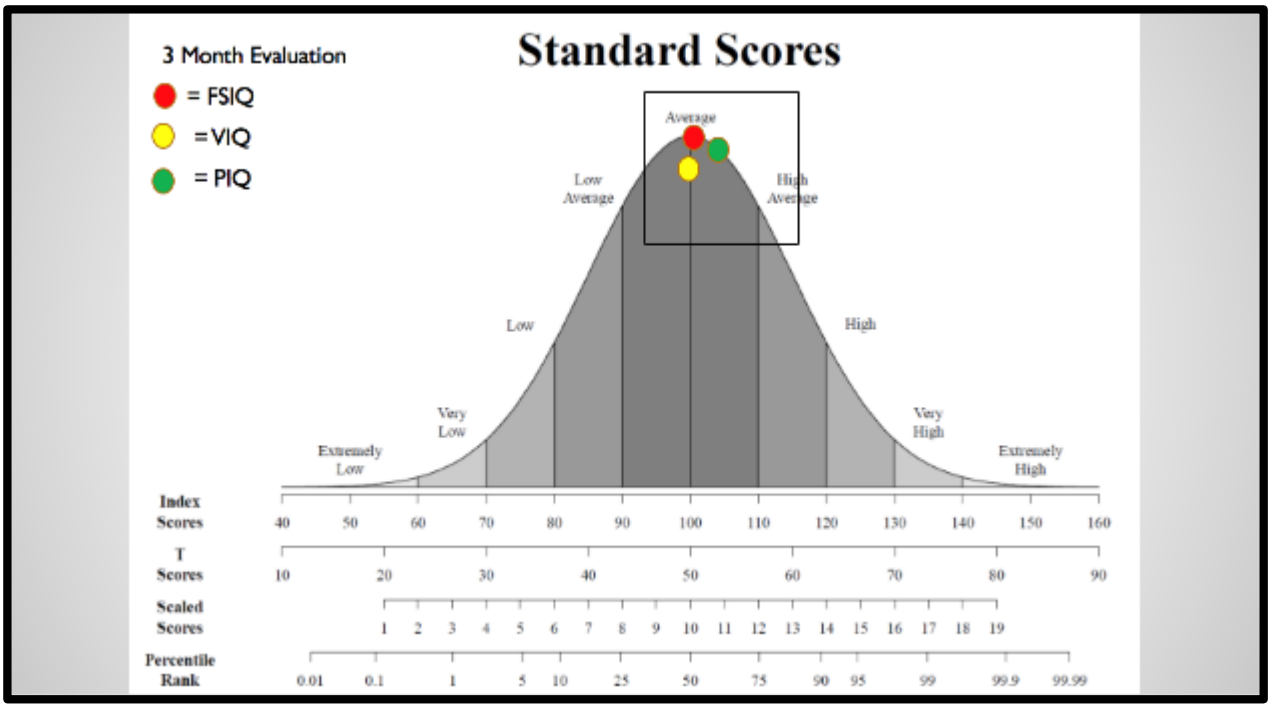
WAIS-III Indicies at 3 month, 19 month and 49 month evaluations

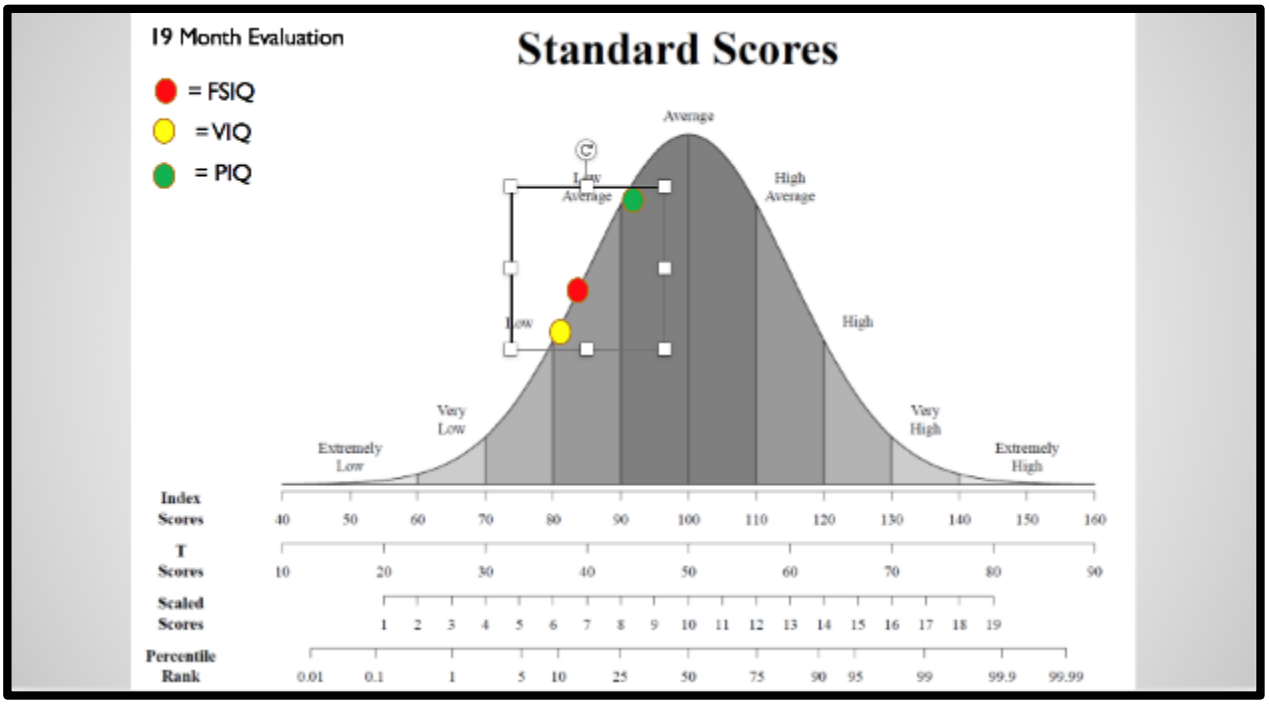
	3 month (%iles)	19 month (%iles)	49 month (%iles)
Full Scale IQ	101 (53%)	86 (18%)	67 (0.2%)
Verbal IQ	99 (47%)	82 (12%)	60 (0.4%)
Performance IQ	104 (61%)	92 (30%)	60 (0.4%)
Verbal Comprehension Index	107 (68%)	94 (34%)	59 (0.3%)
Perceptual Organization Index	103 (58%)	95 (37%)	67 (1%)
Working Memory Index	Not Reported	Not Reported	59 (0.3%)
Processing Speed Index	Not Reported	Not Reported	63 (1%)

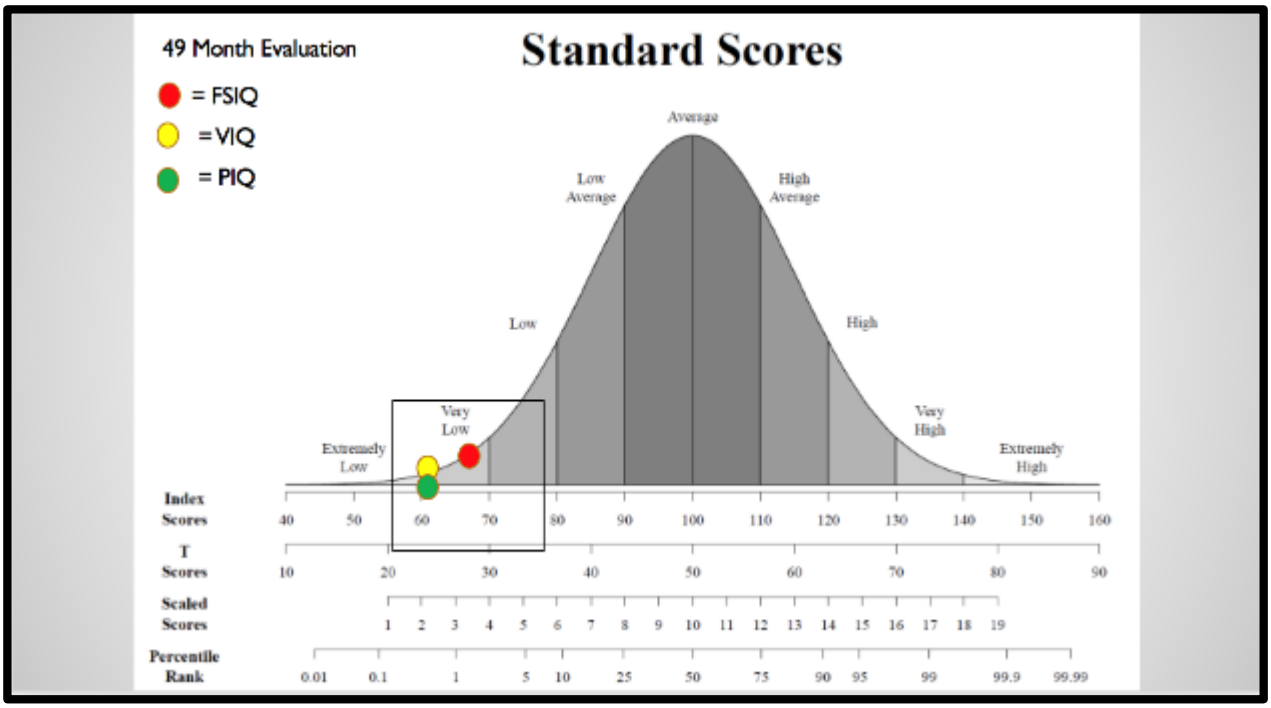
	3-month	19-month	49-month
Verbal IQ	99	82	59
Perceptual IQ	104	92	60

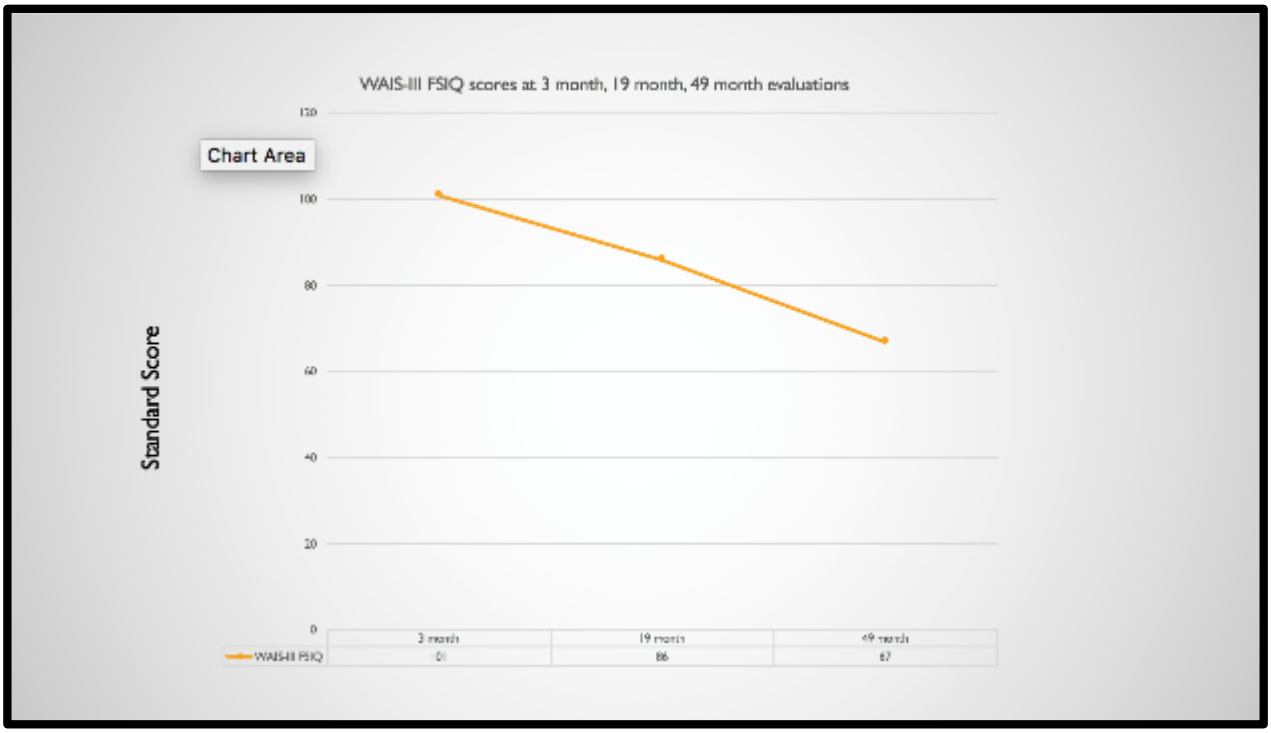
A paired-sample *T*-test was conducted : no significant difference noted 3-month (M=101.5, SD=3.535) and 19-month (M=87, SD=7.071) conditions; t(2)=2.594, p=0.122.

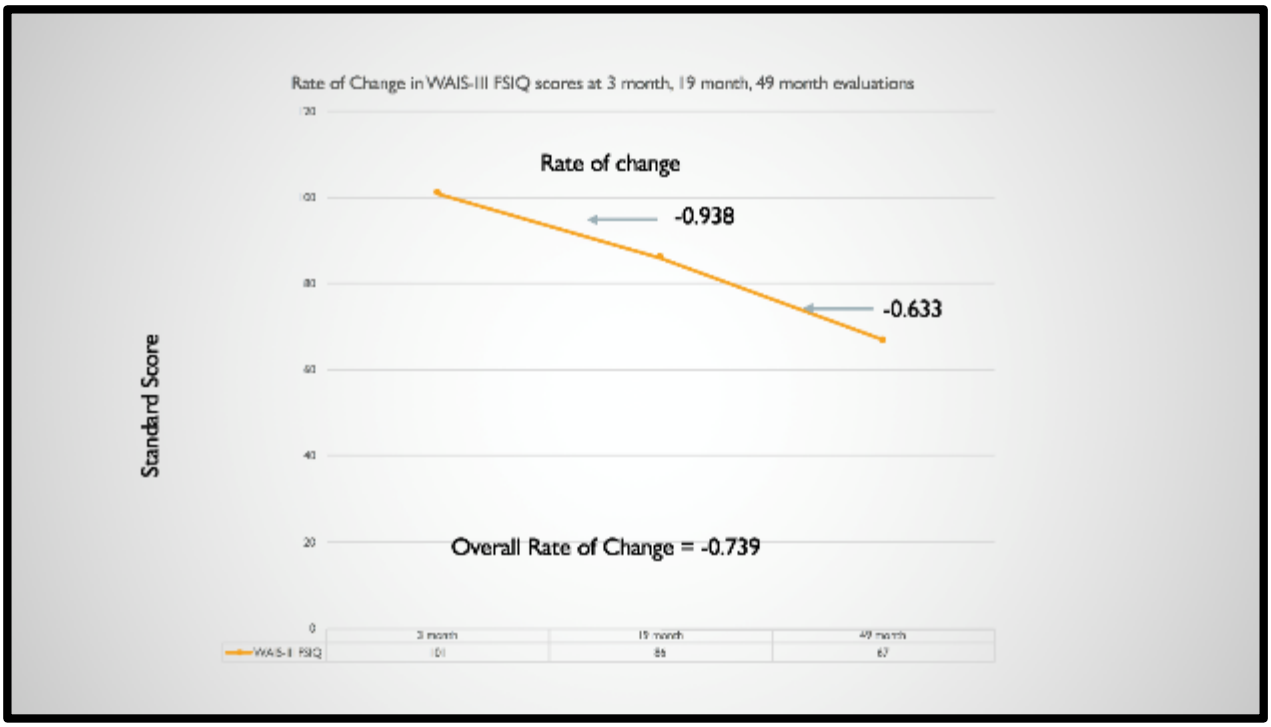
Significant difference between the scores for 19-month (M=87, SD=7.07) and 49-month (M=59.5, SD=0.707) conditions; t(2)=5.473, p=0.032.

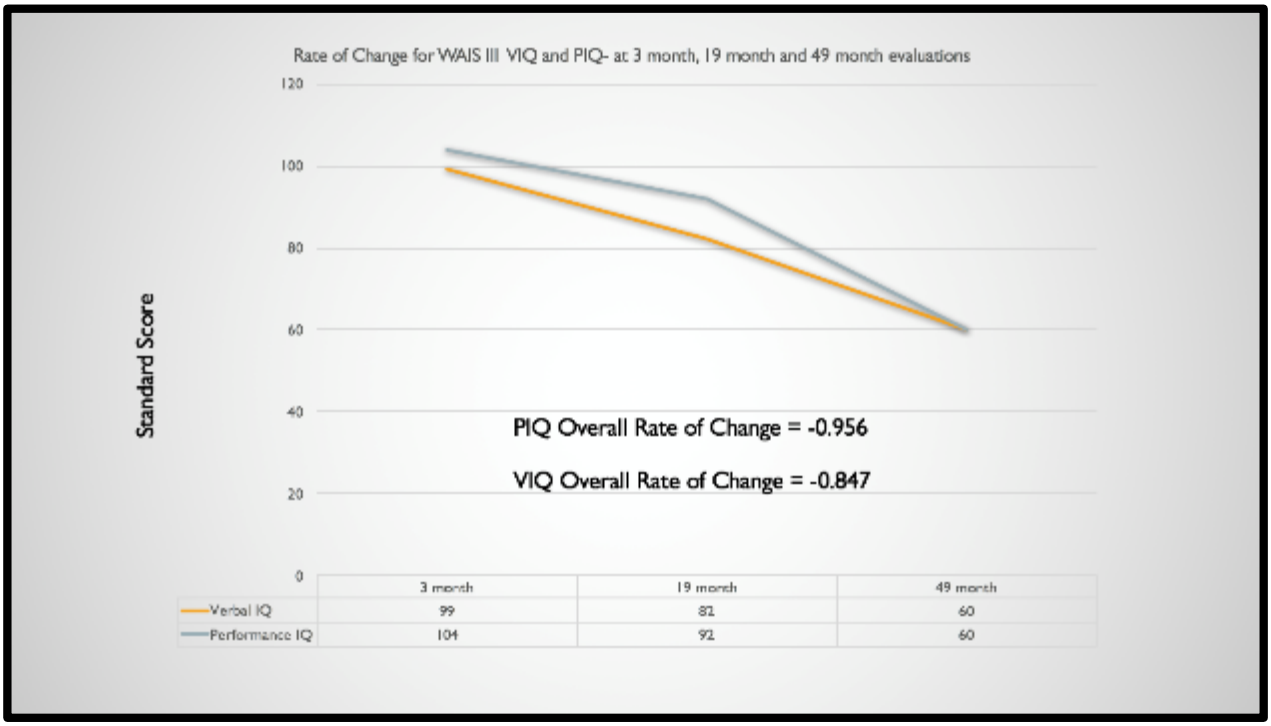

3 Month Evaluation
= FSIQ
= VIQ
= PIQ
Standard Scores
Average
Low Average
High Average
Low
High
Very Low
Very High
Extremely Low
Extremely High
Index Scores
40 50 60 70 80 90 100 110 120 130 140 150 160
T Scores
10 20 30 40 50 60 70 80 90
Scaled Scores
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Percentile Rank
0.01 0.1 1 5 10 25 50 75 90 95 99 99.9 99.99

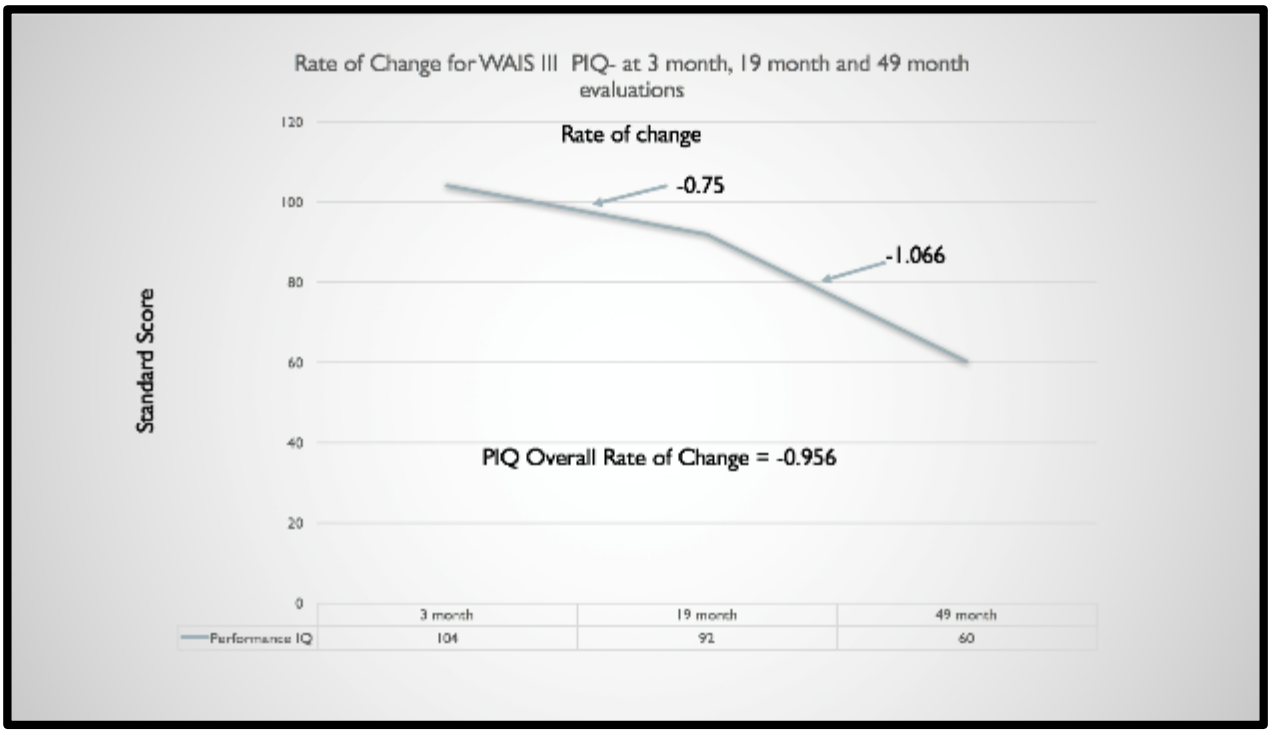

19 Month Evaluation
= FSIQ
= VIQ
= PIQ
Standard Scores
Average
Low Average
High Average
Low
High
Very Low
Very High
Extremely Low
Extremely High
Index Scores
40 50 60 70 80 90 100 110 120 130 140 150 160
T Scores
10 20 30 40 50 60 70 80 90
Scaled Scores
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Percentile Rank
0.01 0.1 1 5 10 25 50 75 90 95 99 99.9 99.99

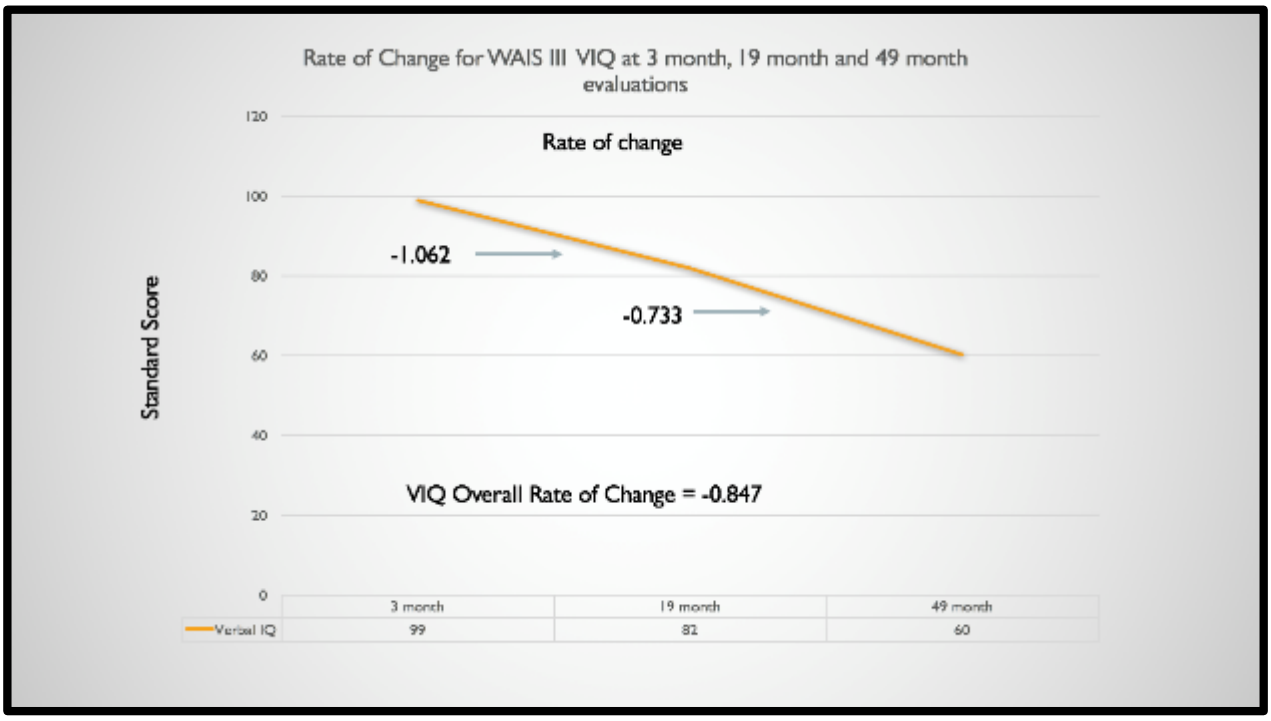

49 Month Evaluation
= FSIQ
= VIQ
= PIQ
Standard Scores
Average
Low Average
High Average
Low
High
Very Low
Very High
Extremely Low
Extremely High
Index Scores
40 50 60 70 80 90 100 110 120 130 140 150 160
T Scores
10 20 30 40 50 60 70 80 90
Scaled Scores
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Percentile Rank
0.01 0.1 1 5 10 25 50 75 90 95 99 99.9 99.99


WAIS-III FSIQ scores at 3 month, 19 month, 49 month evaluations
Chart Area
Standard Score
120
100
80
60
40
20
0
3 month
19 month
49 month
WAIS-III FSIQ
86
87


Rate of Change in WAIS-III FSIQ scores at 3 month, 19 month, 49 month evaluations
Rate of change
-0.938
-0.633
Standard Score
Overall Rate of Change = -0.739
3 month
19 month
49 month
WAIS-II FSIQ
101
86
67


Rate of Change for WAIS III VIQ and PIQ- at 3 month, 19 month and 49 month evaluations
120
100
80
60
40
20
0
Standard Score
PIQ Overall Rate of Change = -0.956
VIQ Overall Rate of Change = -0.847
3 month
19 month
49 month
Verbal IQ
99
82
60
Performance IQ
104
92
60


Rate of Change for WAIS III PIQ- at 3 month, 19 month and 49 month evaluations
Rate of change
-0.75
-1.066
PIQ Overall Rate of Change = -0.956
Standard Score
120
100
80
60
40
20
0
3 month
19 month
49 month
Performance IQ
104
92
60

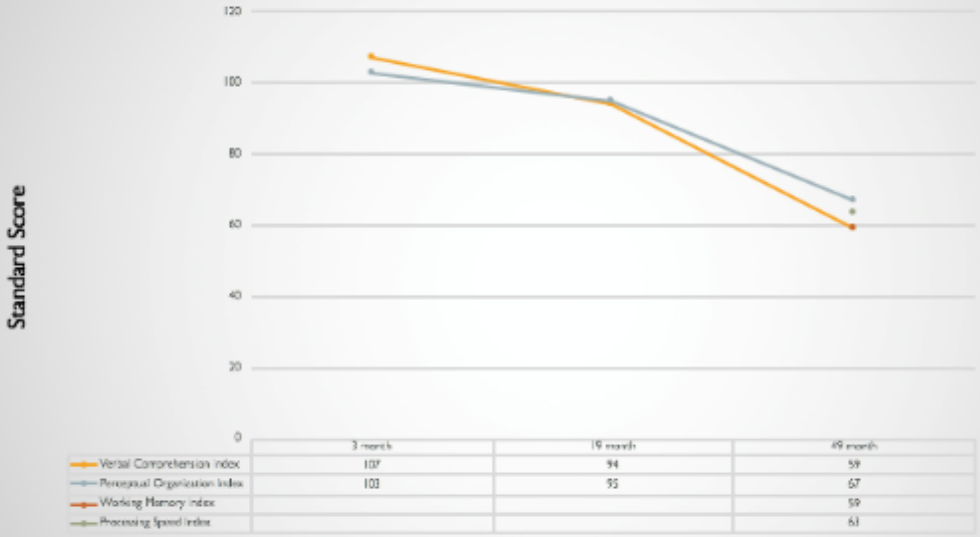

Rate of Change for WAIS III VIQ at 3 month, 19 month and 49 month evaluations
Rate of change
-1.062
-0.733
VIQ Overall Rate of Change = -0.847
Standard Score
120
100
80
60
40
20
0
3 month
19 month
49 month
Verbal IQ
99
82
60

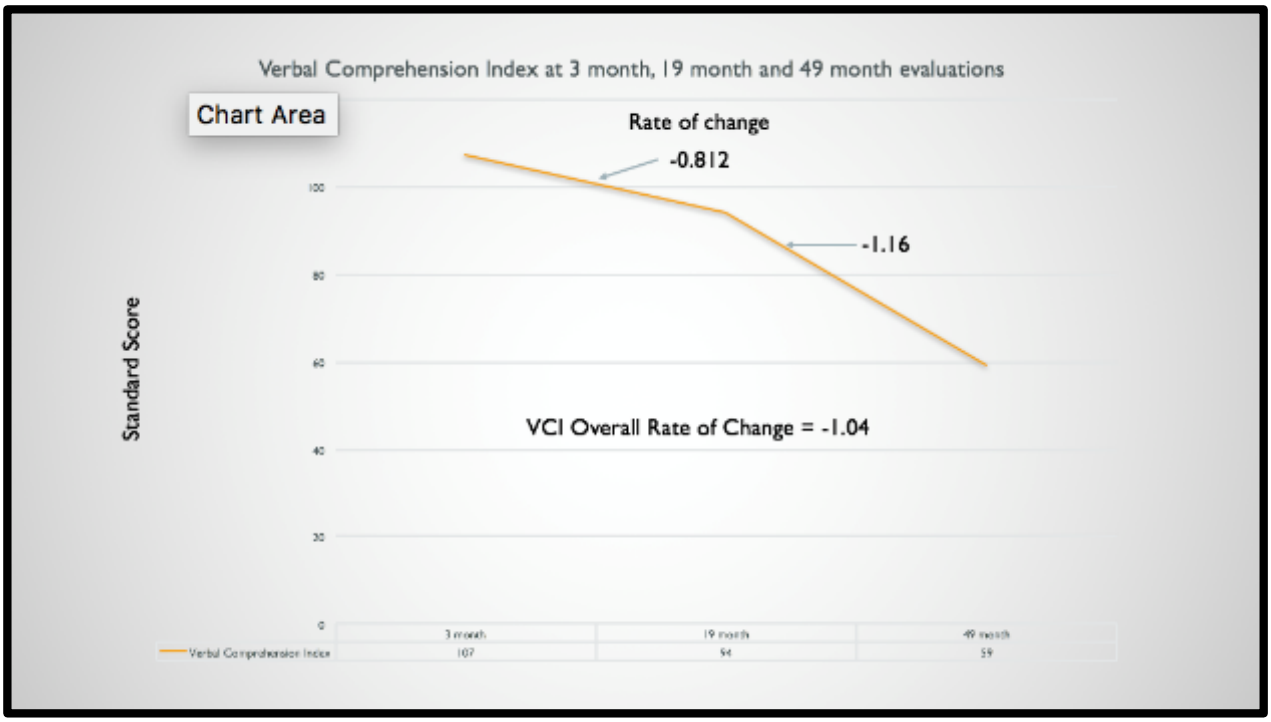
Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) Composite estimated changes between 3-month and 19-month and 19-month and 49-month assessments

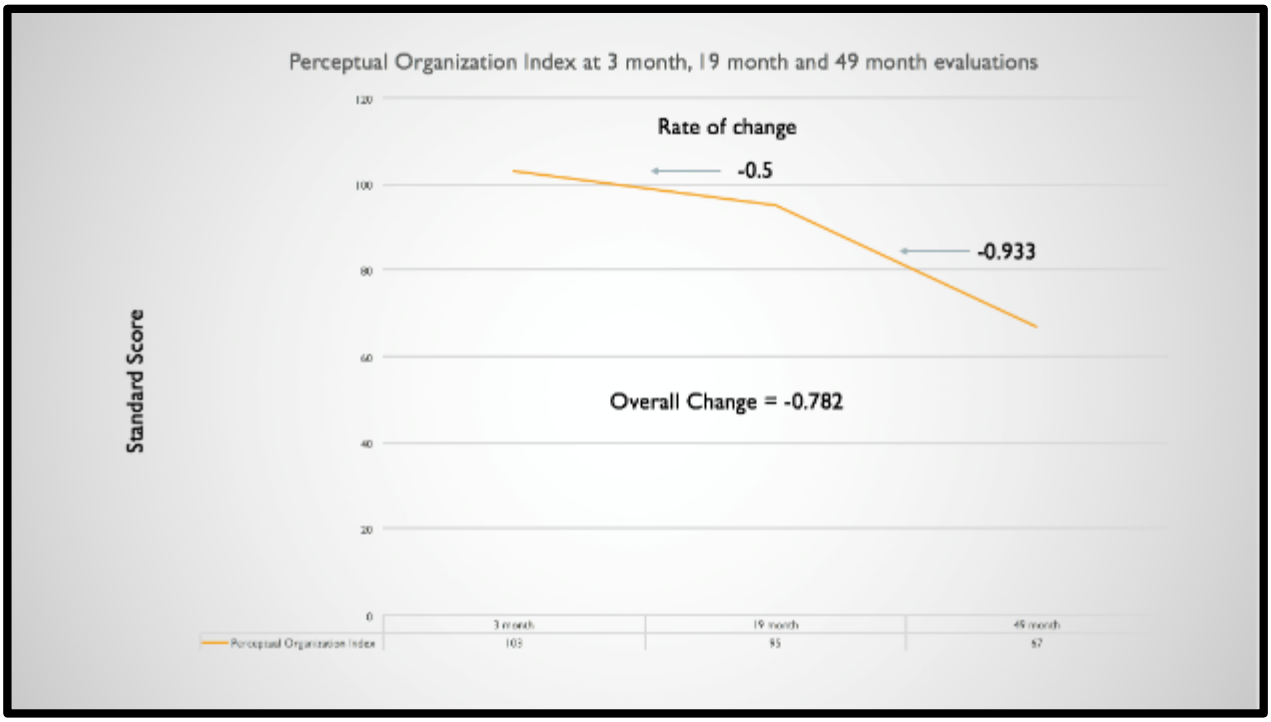
Subtests	3-month to 19-month change in score	19-month to 49-month change in score
Verbal IQ (VIQ)	-1.0625	-0.733
Performance IQ (PIQ)	-0.75	-1.066

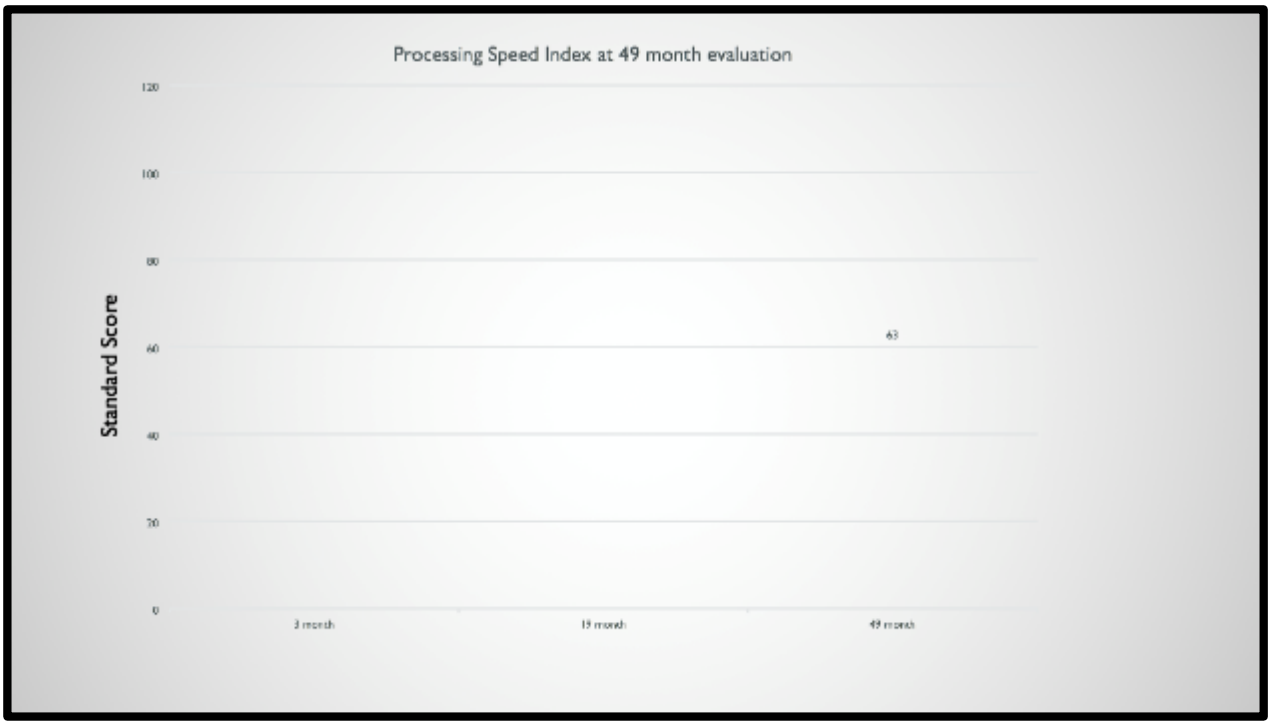
The rate of change for VIQ and PIQ is not statistically significant for 3-month to 19-month change (M=-0.906, SD=0.220) and 19-month to 49-month (M=-0.899, SD=0.235) conditions; $t(2)=-0.030$, $p = 0.490$.

WAIS-III VCI, POI, WMI and PSI standard scores at 3 month, 19 month, and 49 month evaluation




Verbal Comprehension Index at 3 month, 19 month and 49 month evaluations
Chart Area
Rate of change
-0.812
-1.16
Standard Score
VCI Overall Rate of Change = -1.04
100
80
60
40
20
0
3 month
19 month
49 month
Verbal Comprehension Index
107
94
89


Perceptual Organization Index at 3 month, 19 month and 49 month evaluations
Rate of change
-0.5
-0.933
Standard Score
Overall Change = -0.782
120
100
80
60
40
20
0
3 month
19 month
49 month
Perceptual Organization Index
103
95
87


Processing Speed Index at 49 month evaluation
Standard Score
120
100
80
60
40
20
0
63
3 month
19 month
49 month


Working Memory Index at 49 month evaluation
Standard Score
120
100
80
60
40
20
0
59
3 month
19 month
49 month

	3-month	19-month	49-month
VCI	107	94	59
POI	103	95	67

Significant difference noted 3-month (M=105, SD=2.82) and 19-month (M=94, SD=0.707) conditions; t(2)=5.093, p =0.036.

Significant difference between the scores for 19-month (M=94.5, SD=0.707) and 49-month (M=63, SD=5.65) conditions; t(2)=7.814, p=0.016.

Could not evaluate WMI and PSI due to lack of Index data

WAIS-III Indicies	Overall Rate of Change from 3 month evaluation to 49 month evaluation	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
FSIQ	-0.739	-0.938	-0.633
PIQ	-0.956	-0.75	-1.066
VIQ	-0.847	-1.062	-0.733
VCI	-1.04	-0.812	-1.16
POI	-0.782	-0.5	-0.933
WMI	Unknown	Unknown	Unknown
PSI	Unknown	Unknown	Unknown

WAIS-III Indicies	Absolute Difference in Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
FSIQ	0.305	-0.938	-0.633
PIQ	0.316	-0.75	-1.066
VIQ	0.329	-1.062	-0.733
VCI	0.348	-0.812	-1.16
POI	0.433	-0.5	-0.933
WMI	Unknown	Unknown	Unknown
PSI	Unknown	Unknown	Unknown

WAIS-III Indicies	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
FSIQ	-0.938	-0.633
PIQ	-0.75	-1.066
VIQ	-1.062	-0.733
VCI	-0.812	-1.16
POI	-0.5	-0.933
WMI	Unknown	Unknown
PSI	Unknown	Unknown

VIQ and PIQ rate of change is not statistically significant when performing a *T*-test for two sample assuming equal variances for 3-month to 19-month change ($M=-0.906$, $SD=0.220$) and 19-month to 49-month ($M=-0.899$, $SD=0.235$) conditions; $t(2)=-0.030$, $p = 0.490$

VCI and POI rate of change is not statistically significant when performing a *T*-test for two sample assuming equal variances for 3-month to 19-month change ($M=-0.656$, $SD=0.221$) and 19-month to 49-month ($M=-1.0495$, $SD=0.1647$) conditions; $t(2)=2.018$, $p = 0.181$.

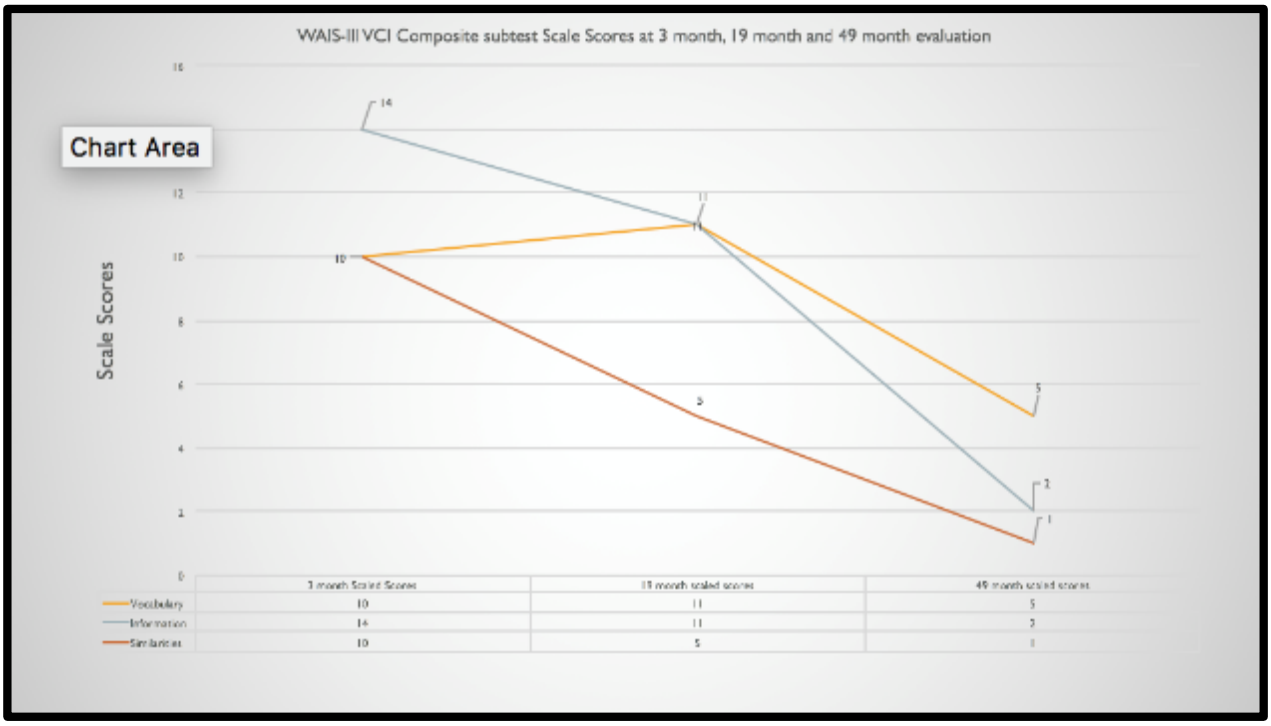
WAIS-III Subtests at 3 month, 19 month and 49 month evaluations

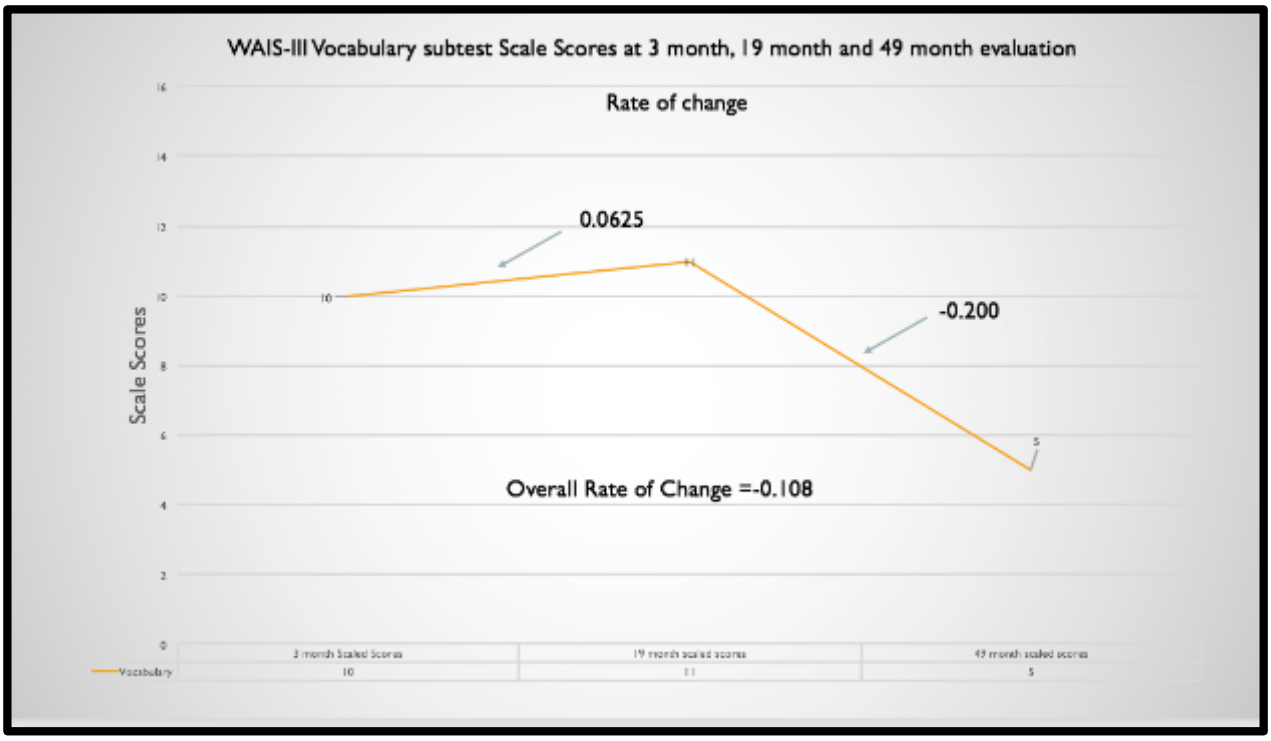
	Subtests	3 month Scaled Scores	19 month scaled scores	49 month scaled scores
VIQ	VCI			
	Vocabulary	10 (50%)	11 (63%)	5 (5%)
	Information	14 (91%)	11 (63%)	2 (0.4%)
	Similarities	10 (50%)	5 (5%)	1 (0.1%)
	WMI			
	Arithmetic	10 (50%)	7 (16%)	5 (5%)
	Digit Span	7 (16%)	5 (5%)	4 (2%)
	Letter number sequencing	Not administered	Not administered	1 (0.1%)
	Comprehension	9 (37%)	3 (1%)	1 (0.1%)
PIQ	POI			
	Picture Completion	7 (16%)	8 (25%)	11 (63%)
	Block Design	11 (63%)	9 (36%)	1 (0.1%)
	Matrix Reasoning	14 (91%	11 (63%)	1 (0.1%)
	PSI			
	Digit Symbol	11 (63%)	10 (50%)	2 (0.4%)
	Symbol Search	Not administered	Not administered	3 (1%)
	Picture Arrangement	10 (50%)	7 (16%)	Not able to complete
	Object assembly	not reported	not reported	2 (0.4%)

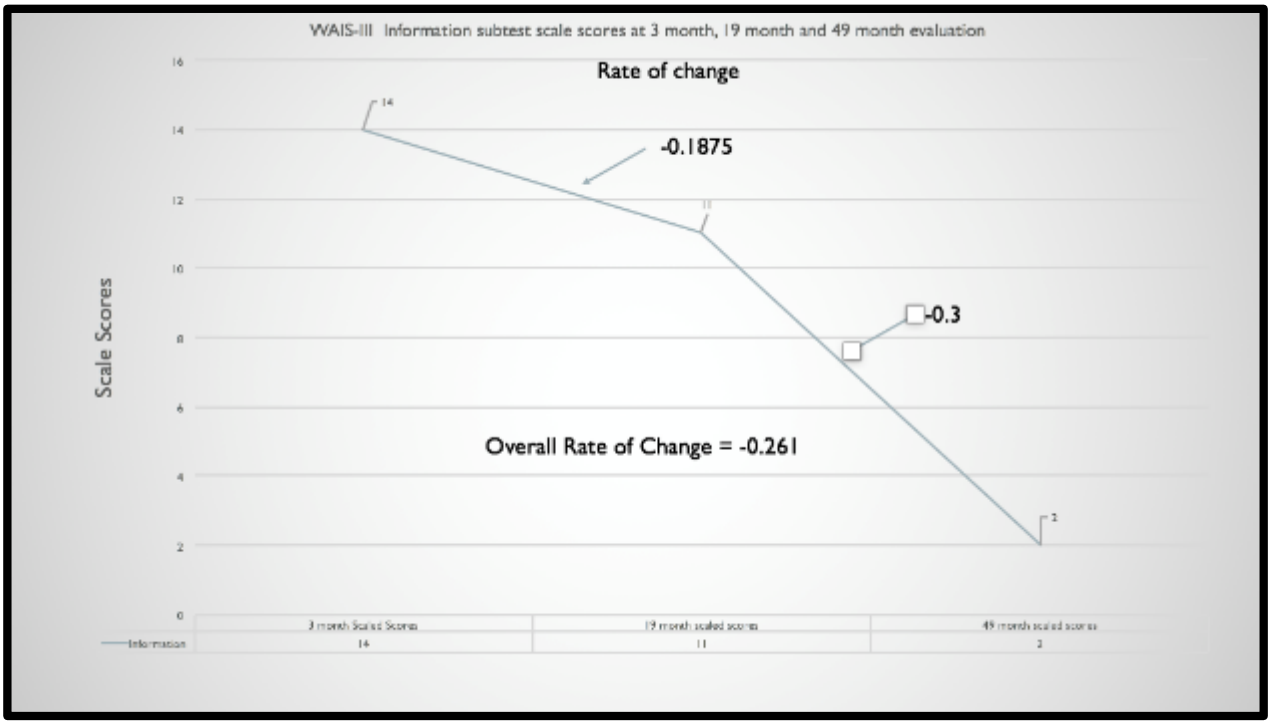
Examining all of the available subtest scores and omitting Letter Number Sequencing and Object Assembly from the 49-month evaluation.

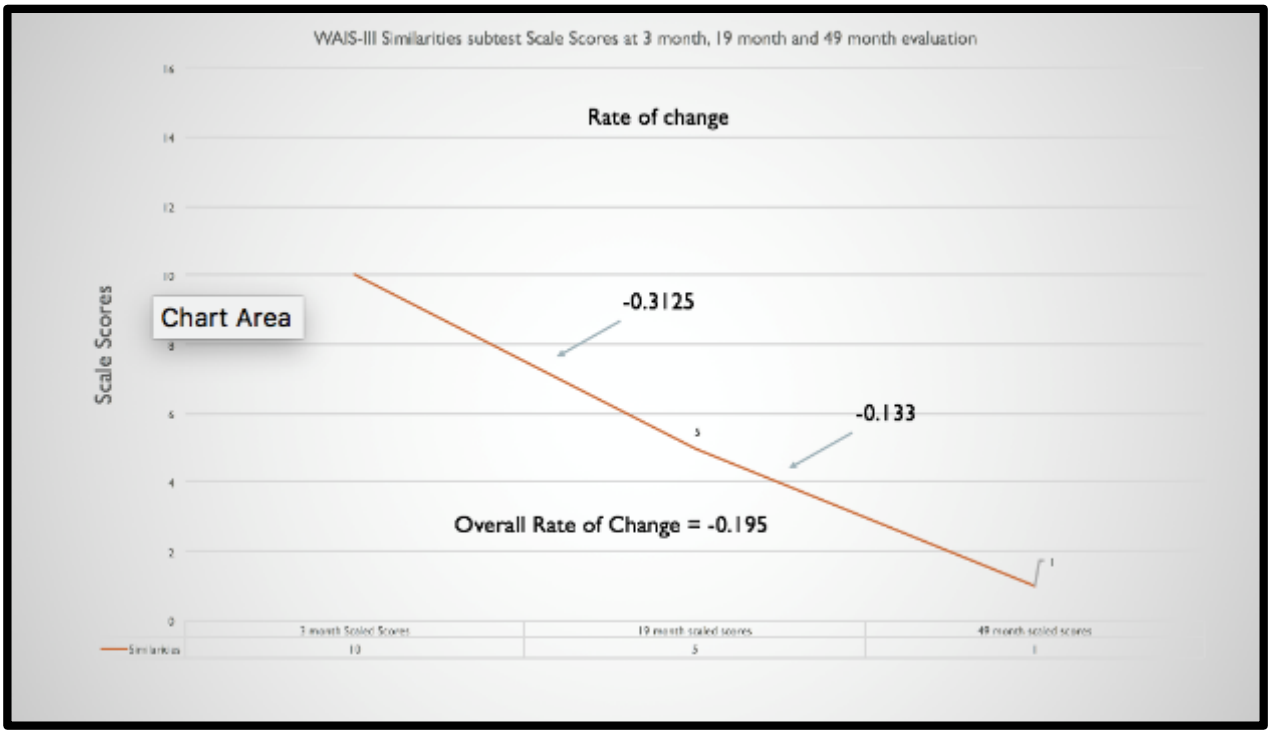
- There was a significant difference between the scaled scores for 3-month (M=-10.272, SD=2.284) evaluation and 19-month (M=7.909, SD=2.773) evaluation; $t(20)=2.182$, $p = 0.041$
- There was a significant difference ($p<0.01$) between the scaled scores for 19-month (M=7.909, SD=2.773) and 49-month (M=3, SD=3.162) conditions; $t(20)=3.70$, $p = 0.01$.
- Next step is to explore each of the individual constructs of the VCI, WMI, POI, PSI

	Not a Significant Difference	Significant Difference
VIQ	N/A	19 -49 month p = 0.032
PIQ	N/A	19-49 month p = 0.032.
VCI -POI	N/A	3-19month at p = 0.036.
VCI -POI	N/A	3-19 month p = 0.016.
All available except for LNS and OA.	N/A	3-19 month p = 0.041
All available except for LNS and OA.	N/A	19-49-month p = 0.01




WAIS-III Vocabulary subtest Scale Scores at 3 month, 19 month and 49 month evaluation
Rate of change
Scale Scores
0.0625
-0.200
Overall Rate of Change =-0.108
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Vocabulary
10
11
5


WAIS-III Information subtest scale scores at 3 month, 19 month and 49 month evaluation
Rate of change
Scale Scores
-0.1875
-0.3
Overall Rate of Change = -0.261
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Information
14
11
2



WAIS-III VCI Subtests Change in Scaled Score with Overall Rate of Change

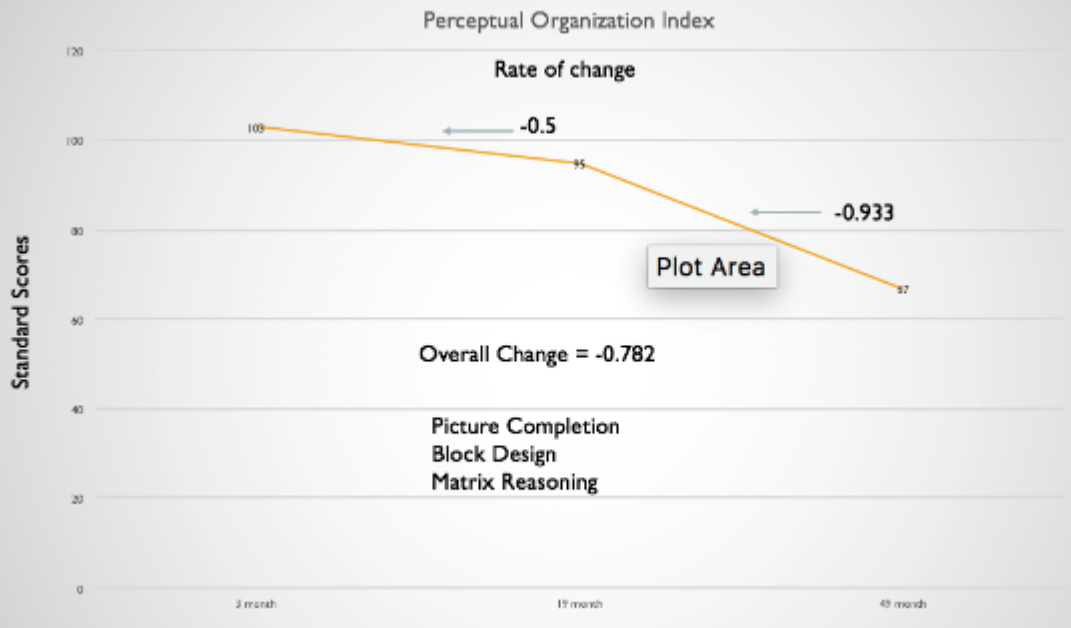
	Overall Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Vocabulary	-0.108	0.0625	-0.2
Information	-0.261	-0.1875	-0.3
Similarities	-0.195	-0.3125	-0.133

Red= Time interval with most change

WAIS-III VCI Subtests Change in Scaled Score with Absolute Difference in Rate of Change

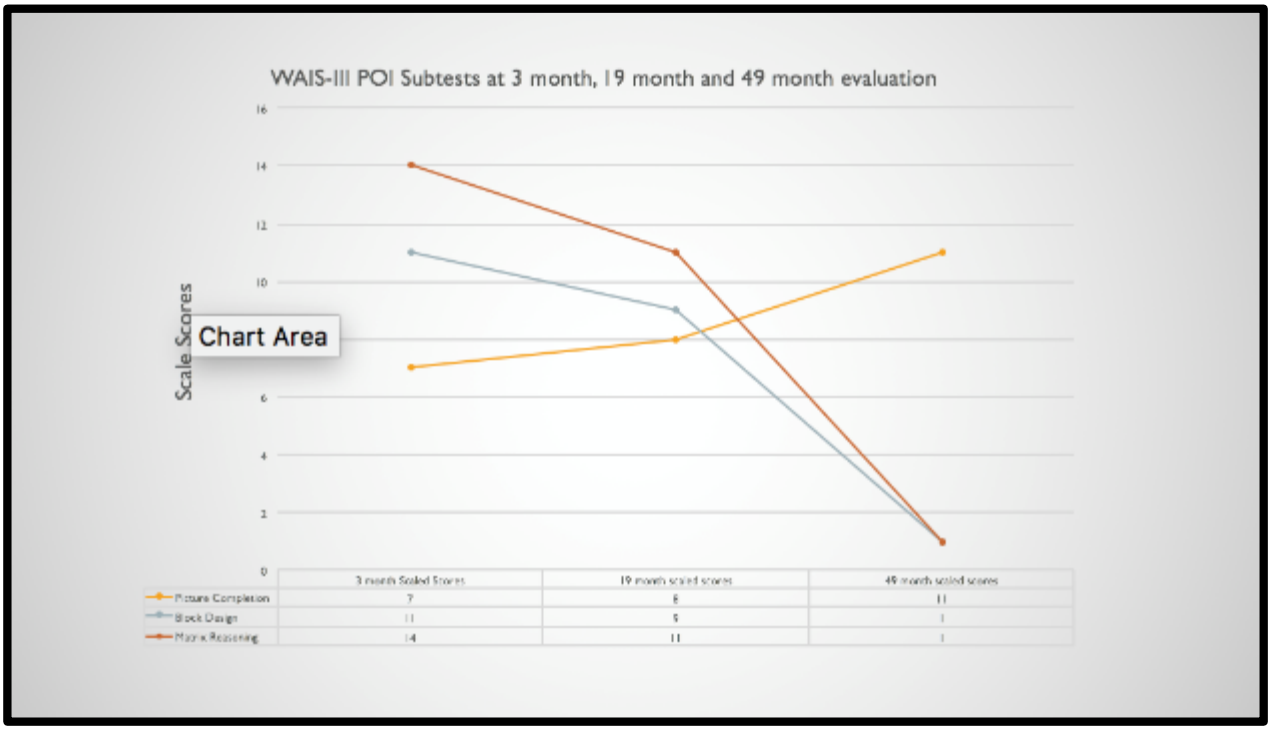
	Absolute Difference in Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Vocabulary	0.2625	0.0625	-0.2
Information	0.1125	-0.1875	-0.3
Similarities	0.1795	-0.3125	-0.133

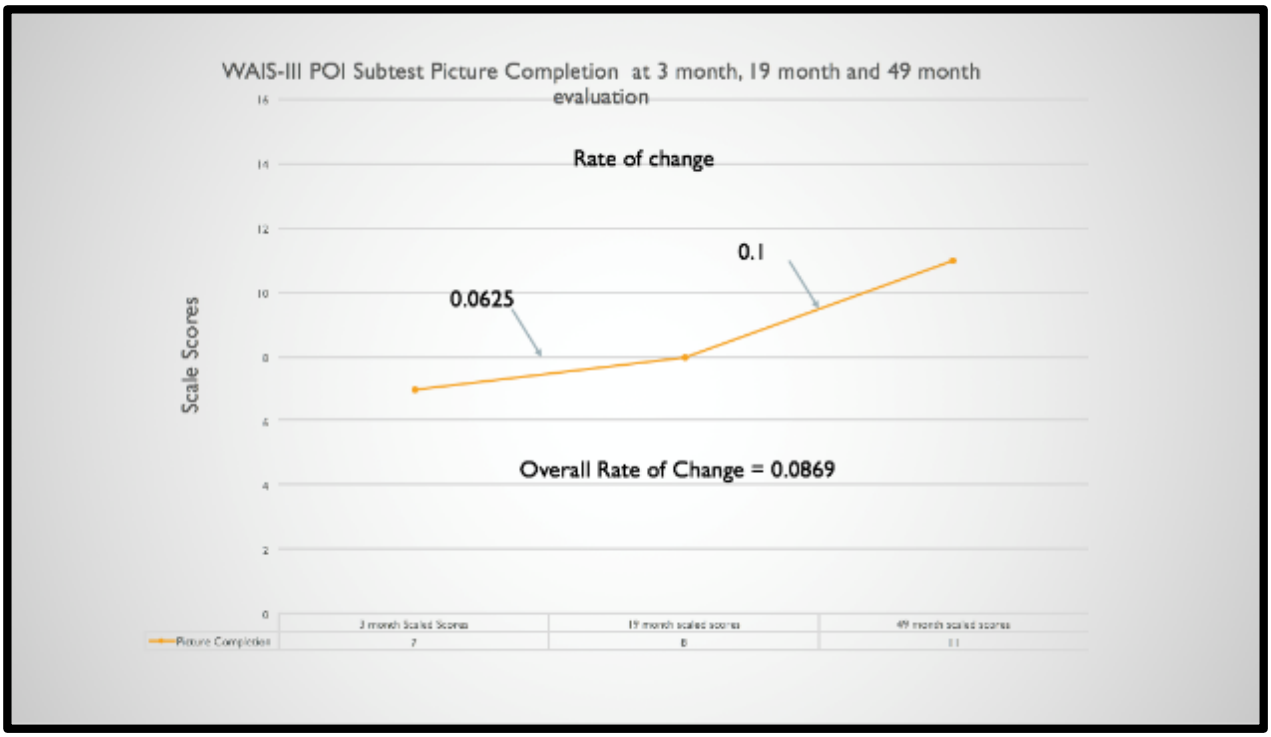
Red= Time interval with most change

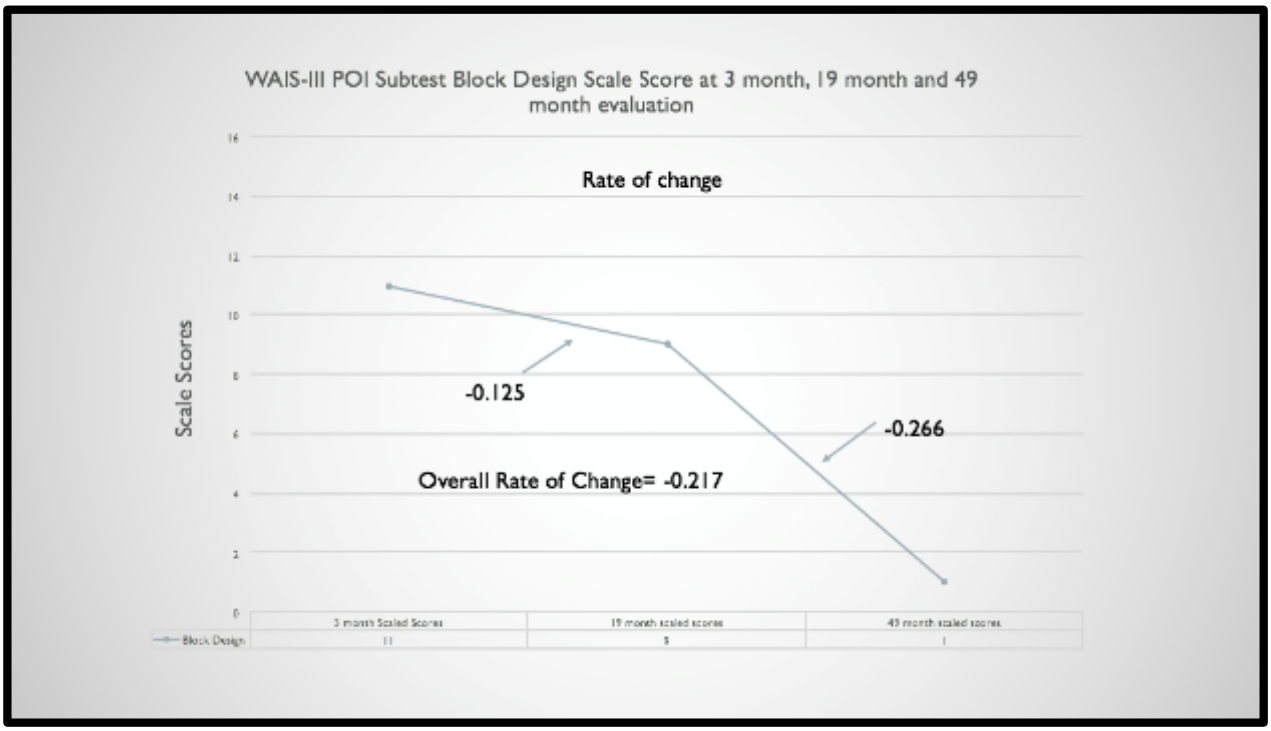


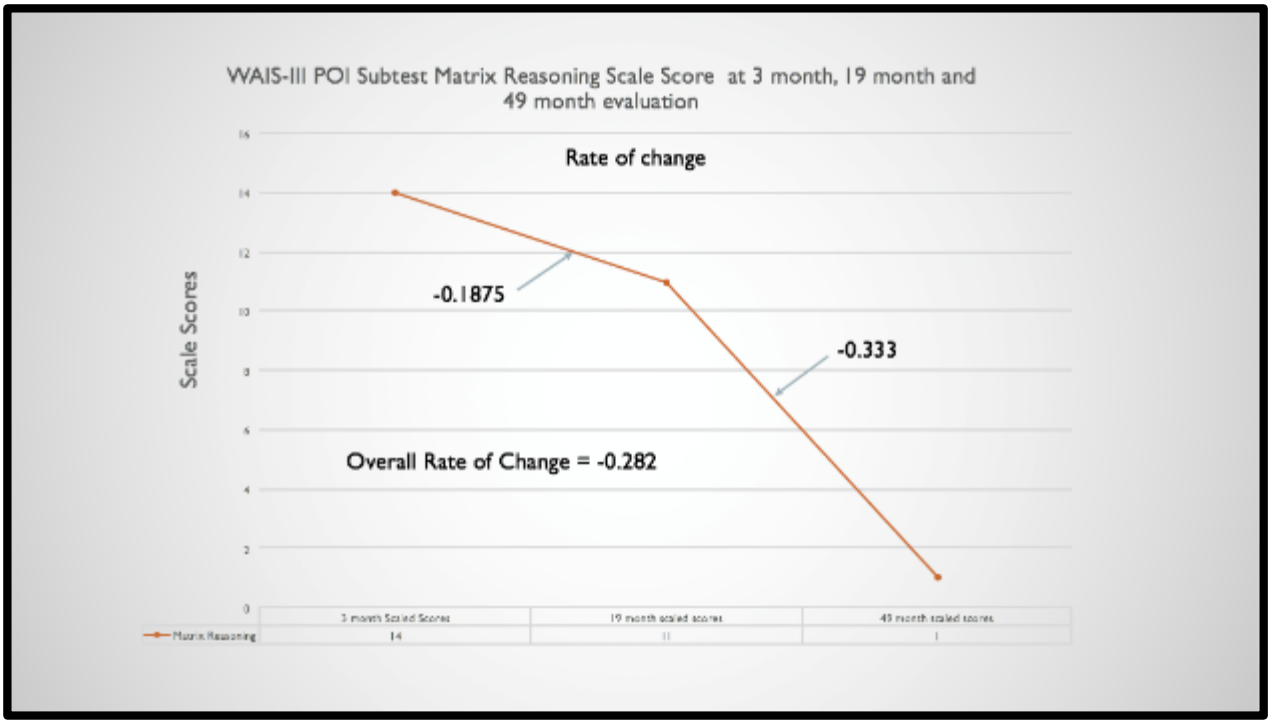
Perceptual Organizational Index

	3 month Scaled Scores	19 month scaled scores	49 month scaled scores
Picture Completion	7	8	11
Block Design	11	9	1
Matrix Reasoning	14	11	1




WAIS-III POI Subtest Picture Completion at 3 month, 19 month and 49 month evaluation
Rate of change
0.0625
0.1
Overall Rate of Change = 0.0869
Scale Scores
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Picture Completion
7
8
11


WAIS-III POI Subtest Block Design Scale Score at 3 month, 19 month and 49 month evaluation
Rate of change
-0.125
-0.266
Overall Rate of Change= -0.217
Scale Scores
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Block Design
11
9
1



Perceptual Organizational Index subtests Overall Rate of Change

	Overall Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Picture Completion	0.0869	0.0625	0.1
Block Design	-0.217	-0.125	-0.266
Matrix Reasoning	-0.282	-0.1875	-0.333

Red= Time frame with most rate of change

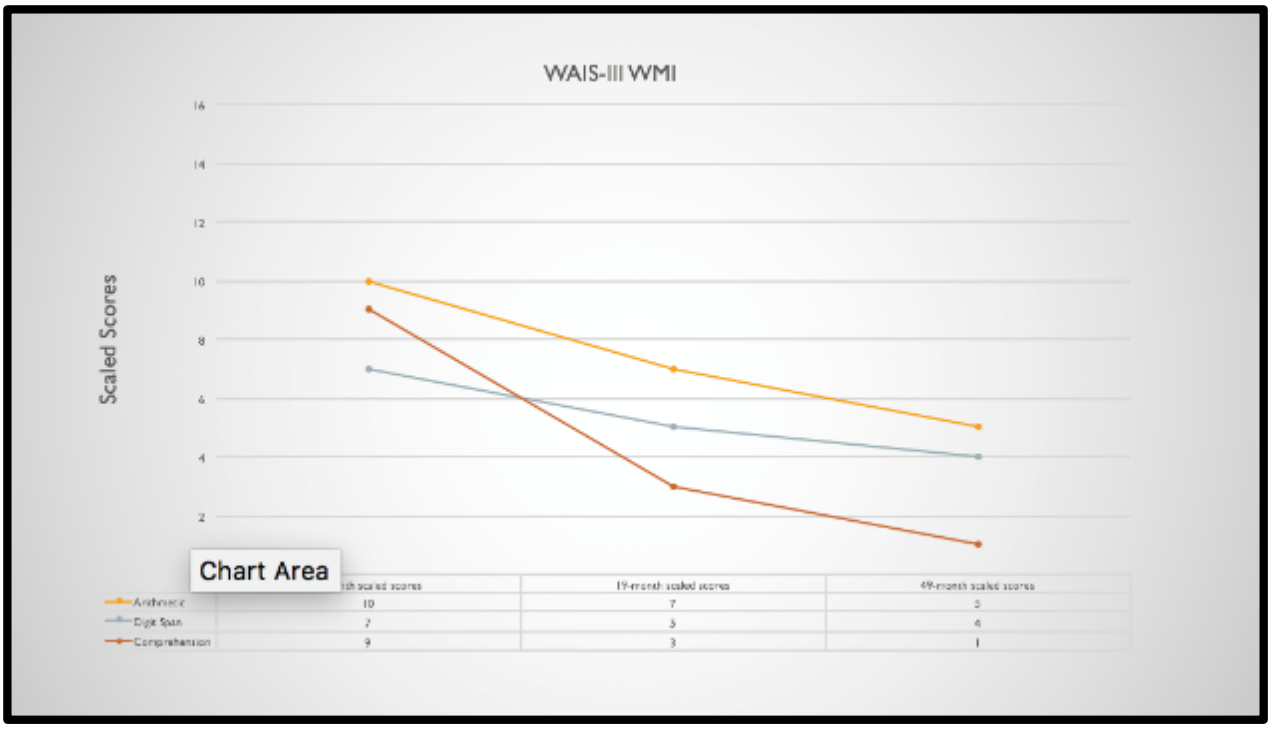
Perceptual Organizational Index with Absolute Difference in Rate of Change

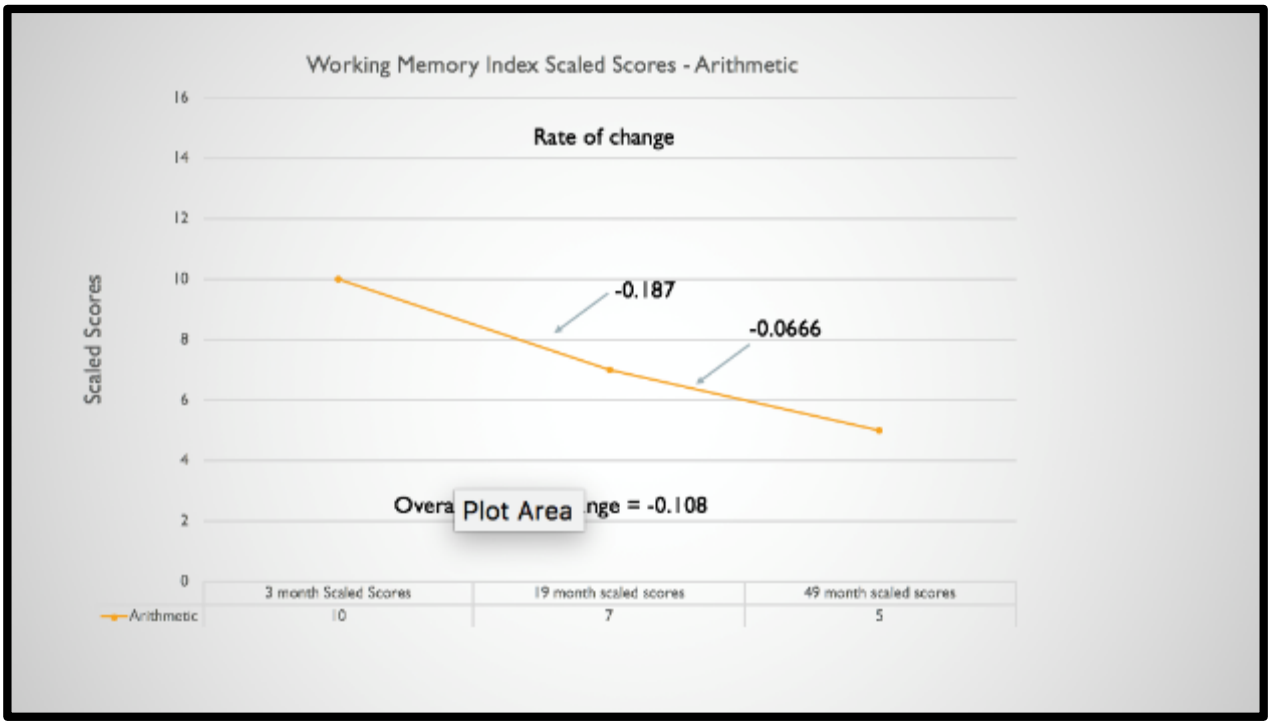
	Absolute Difference in Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Picture Completion	0.0375	0.0625	0.1
Block Design	0.141	-0.125	-0.266
Matrix Reasoning	0.1455	-0.1875	-0.333

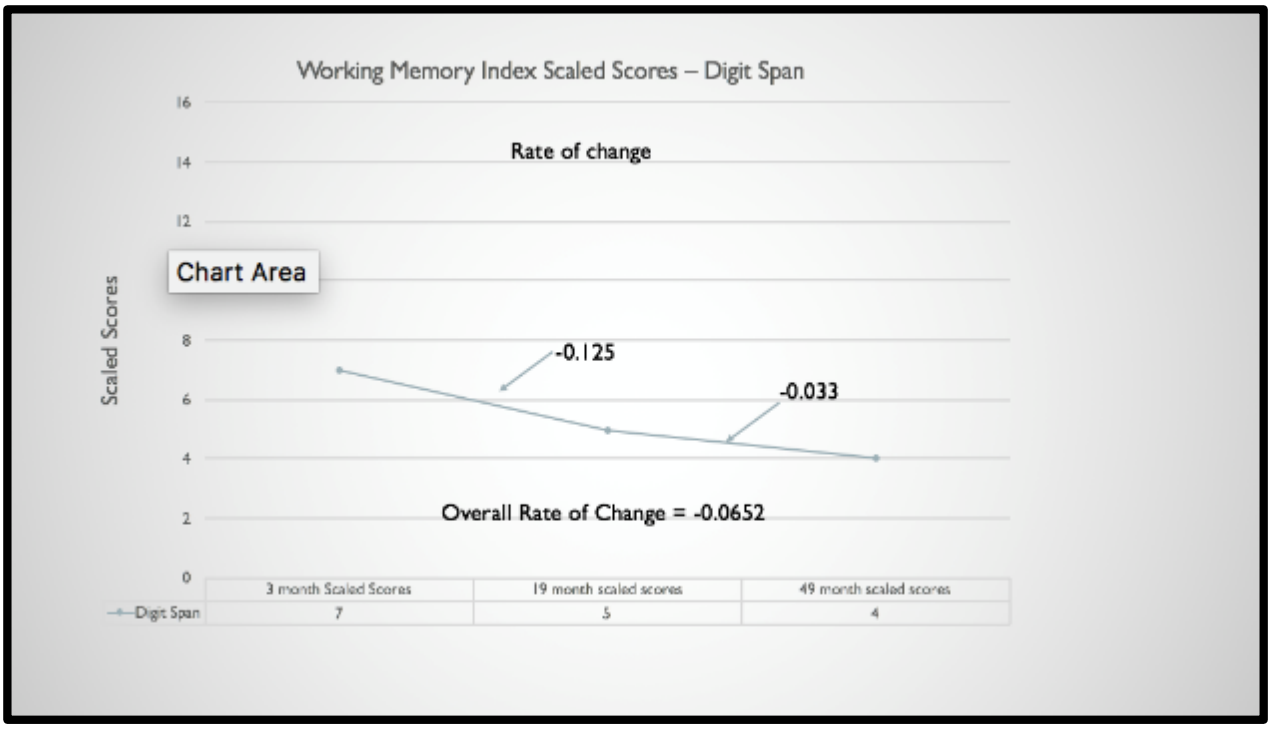
Red= Time frame with most rate of change

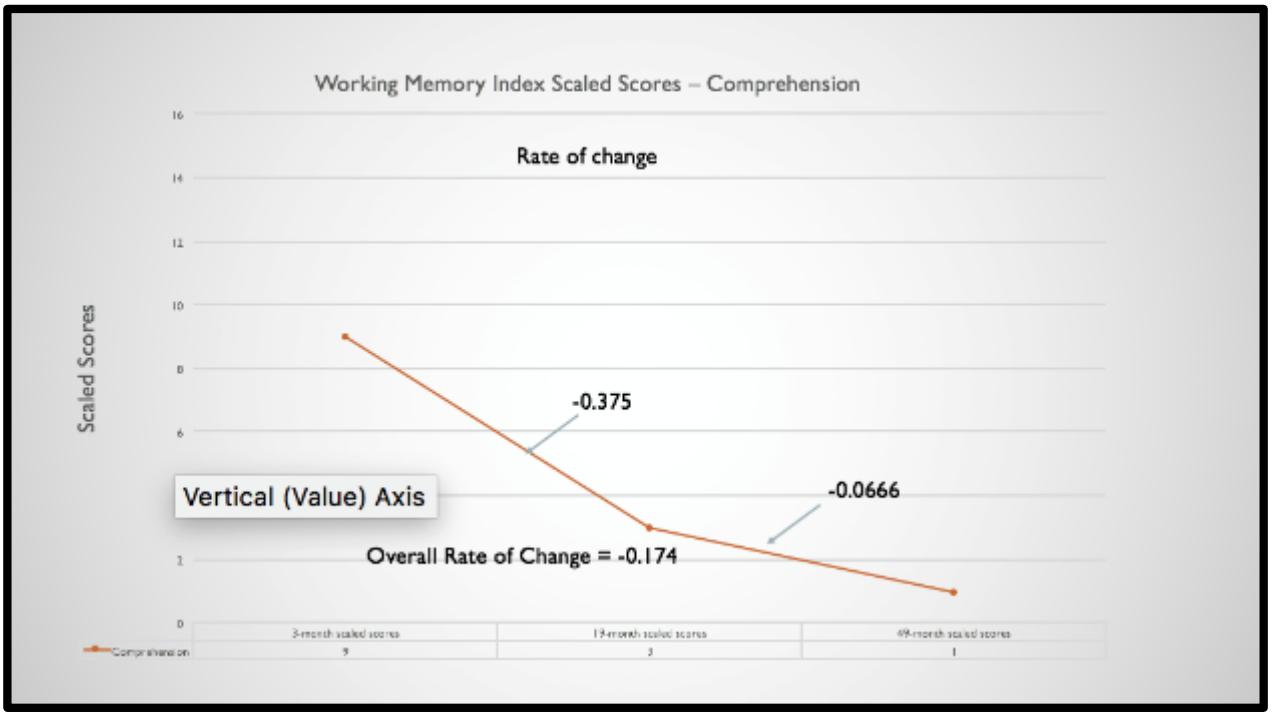
Working Memory Index

	3 month scaled Scores	19 month scaled scores	49 month scaled scores
Arithmetic	10	7	5
Digit Span	7	5	4
Comprehension	9	3	1


WAIS-III WMI
Scaled Scores
16
14
12
10
8
6
4
2
Chart Area
Arithmetic
Digit Span
Comprehension
10
7
5
9
3
1


Working Memory Index Scaled Scores - Arithmetic
Rate of change
Scaled Scores
16
14
12
10
8
6
4
2
0
-0.187
-0.0666
Plot Area
nge = -0.108
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Arithmetic
10
7
5


Working Memory Index Scaled Scores – Digit Span
Rate of change
Chart Area
Scaled Scores
16
14
12
8
6
4
2
0
-0.125
-0.033
Overall Rate of Change = -0.0652
3 month Scaled Scores
19 month scaled scores
49 month scaled scores
Digit Span
7
5
4


Working Memory Index Scaled Scores – Comprehension
Rate of change
Scaled Scores
16
14
12
10
8
6
2
0
-0.375
-0.0666
Vertical (Value) Axis
Overall Rate of Change = -0.174

Working Memory Index

	Overall Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Arithmetic	-0.108	-0.187	-0.0666
Digit Span	-0.0652	-0.125	-0.125
Comprehension	-0.174	-0.375	-0.0666

Red= Time frame with most rate of change

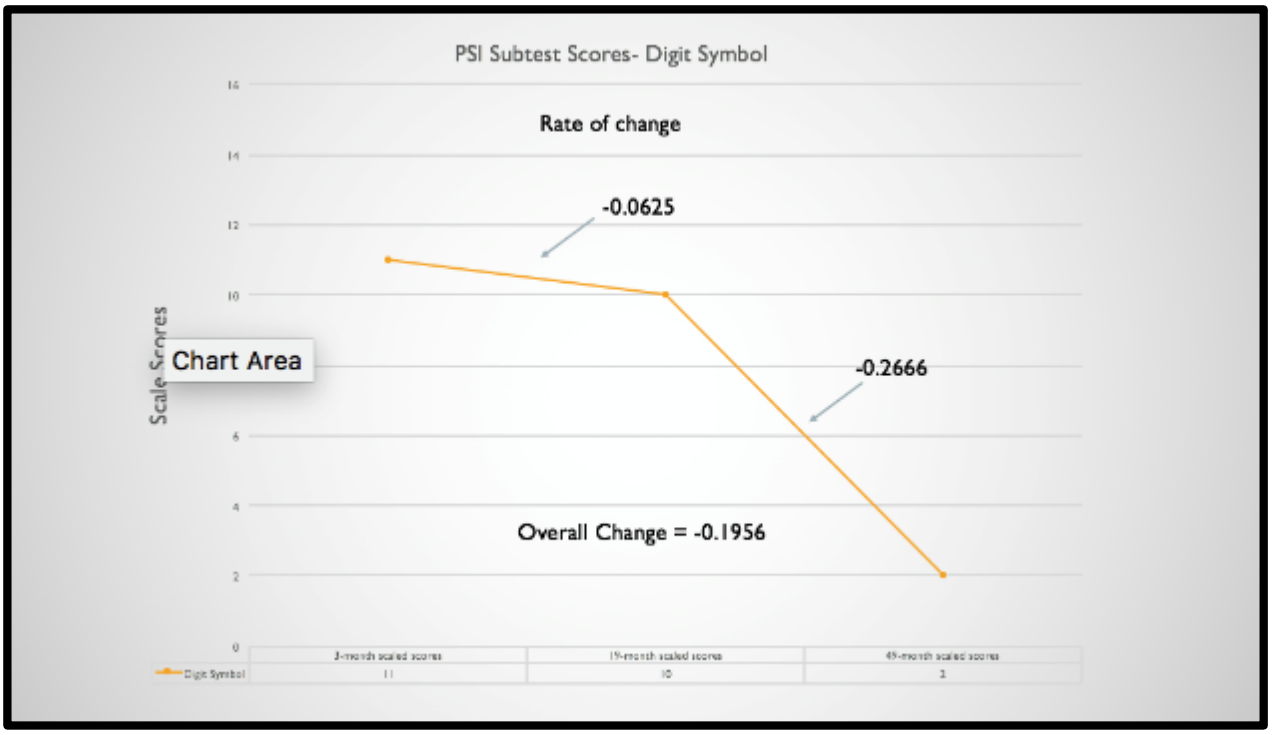
Working Memory Index

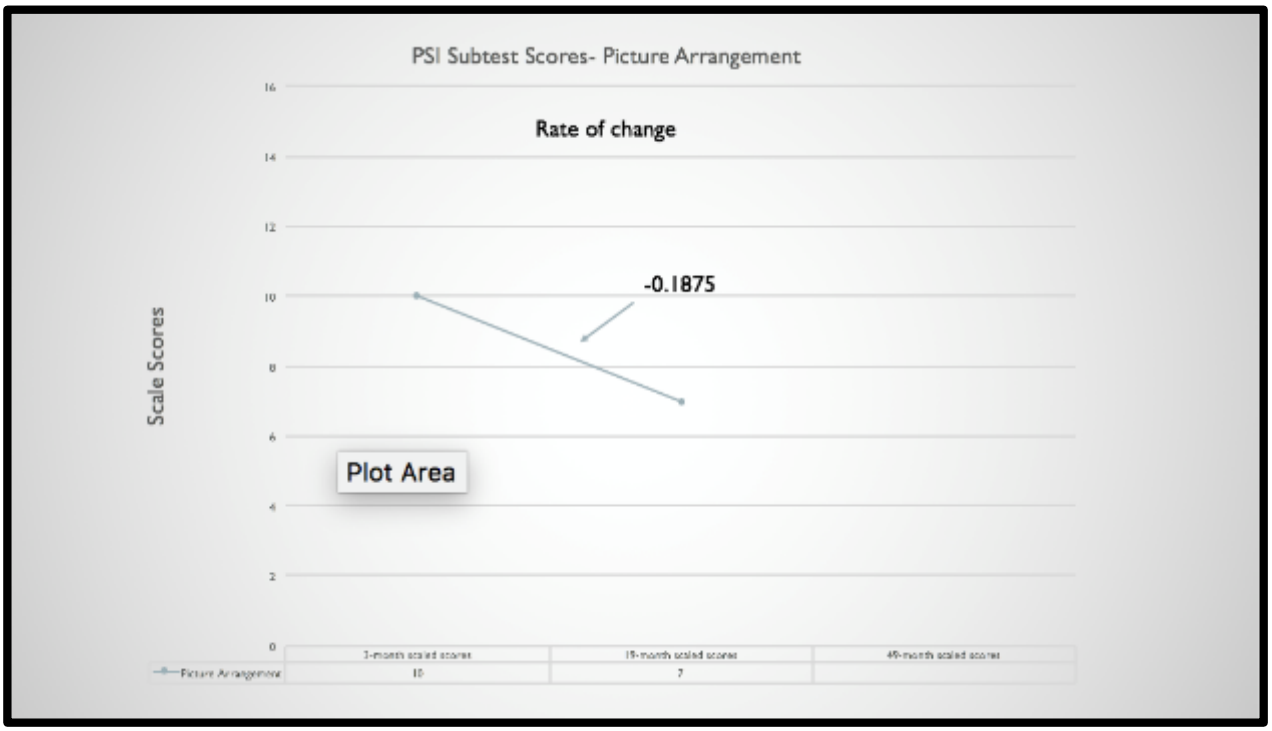
	Absolute Difference in Rate of Change	Rate of Change between 3 month and 19 month evaluation	Rate of Change between 19 month and 49 month evaluation
Arithmetic	0.1204	-0.187	-0.0666
Digit Span	0	-0.125	-0.125
Comprehension	0.3084	-0.375	-0.0666

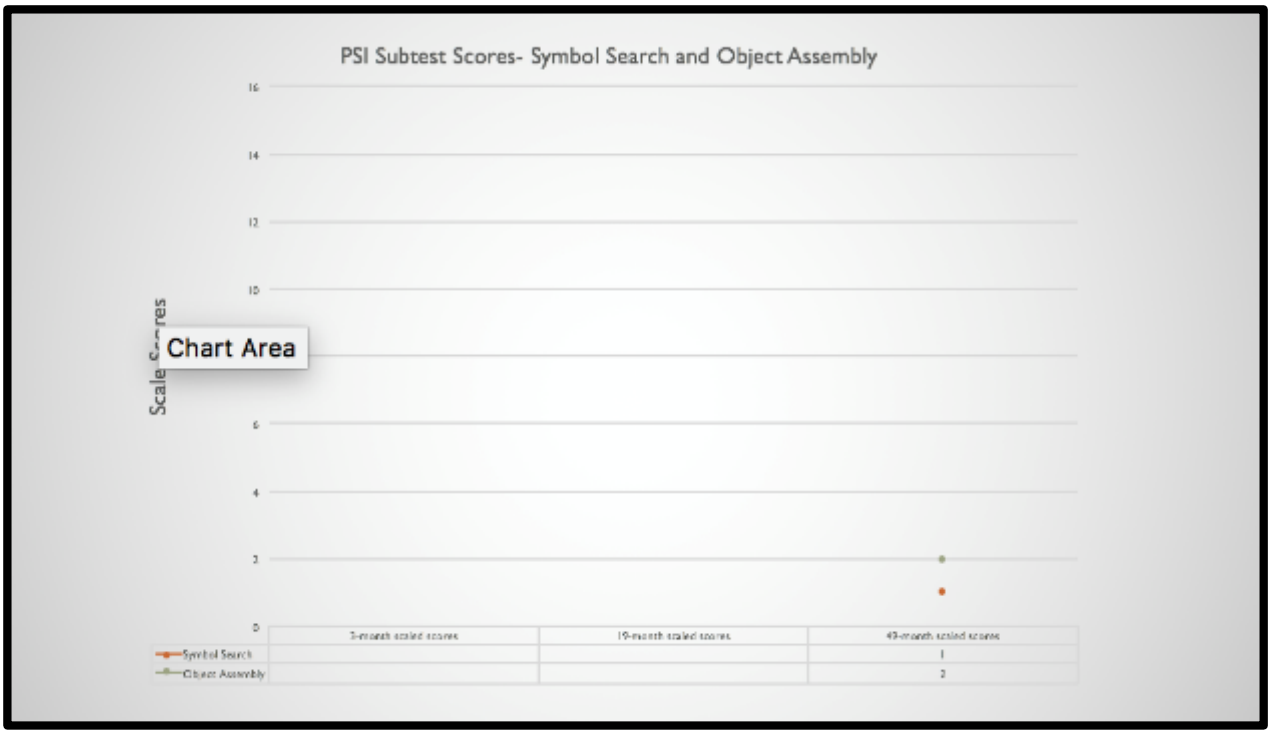
Red= Time frame with most rate of change

Processing Speed Index

	3 month Scaled Scores	19 month scaled scores	49 month scaled scores
Digit Symbol	11	10	2
Picture Arrangement	10	7	Not able to complete
Symbol Search	Not administered	Not administered	1
Object Assembly	Not administered	Not administered	2


PSI Subtest Scores- Digit Symbol
Rate of change
-0.0625
-0.2666
Overall Change = -0.1956
Chart Area
Scale Scores
16
14
12
10
8
6
4
2
0
3-month scaled scores
19-month scaled scores
Digit Symbol
11
10


PSI Subtest Scores- Picture Arrangement
Rate of change
-0.1875
Plot Area
Scale Scores
16
14
12
10
8
6
4
2
0
3-month scaled scores
19-month scaled scores
10
7



WMS-III Subtest average monthly changes in scale scores between 3-month and 19-month evaluation and 19-month and 49-month evaluation

	Subtests	Average change in scale score between 3- month and 19-month evaluation	Average change in scale score between 19-month and 49-month evaluation
VIQ	Vocabulary	0.0625	-0.2
	Similarities	-0.3125	-0.1333
	Information	-0.1875	-0.3
	Arithmetic	-0.1875	-0.0666
	Digit Span	-0.125	-0.03333
	Comprehension	-0.375	-0.0666
	Letter number sequencing	* --	* --
PIQ	Picture Completion	0.0625	0.1
	Block Design	-0.125	-0.2666
	Matrix Reasoning	-0.1875	-0.333
	Digit Symbol	-0.0625	-0.2666
	Coding	* --	* --
	Picture Arrangement	-0.1875	* --
	Symbol Search	* --	* --
	Object assembly	* --	* --

WMS-III Subtest average monthly changes in scale scores between 3-month and 19-month evaluation and 19-month and 49-month evaluation – Incidence of Improvement

	Subtests	Average change in scale score between 3- month and 19-month evaluation	Average change in scale score between 19-month and 49- month evaluation
VIQ	Vocabulary	0.0625	-0.2
	Similarities	-0.3125	-0.1333
	Information	-0.1875	-0.3
	Arithmetic	-0.1875	-0.0666
	Digit Span	-0.125	-0.03333
	Comprehension	-0.375	-0.0666
	Letter number sequencing	* --	* --
PIQ	Picture Completion	0.0625	0.1
	Block Design	-0.125	-0.2666
	Matrix Reasoning	-0.1875	-0.333
	Digit Symbol	-0.0625	-0.2666
	Coding	* --	* --
	Picture Arrangement	-0.1875	* --
	Symbol Search	* --	* --
	Object assembly	* --	* --

INTELLIGENCE CONCLUSIONS

- Improvement noted initially on VIQ-Vocabulary for first 19 months and then a noted deterioration
- Constructs measured by WAIS-III picture completion show improvement after possible TBI while all other constructs show a simultaneous deterioration
- Rate of change after a TBI is noted more in areas reflected in VIQ subtests from months 3-19 and noted more in PIQ subtests from months 19-49.
- There are identical rates of change in subtests from both the VIQ and PIQ.
- Medical records indicate that patient initially underwent speech therapy for a few months after the initial neuropsychological evaluation at the 3 month mark. This could have potentially contributed to the increase in the Vocabulary scores between the 3 month and 19 month evaluation and the deterioration seen between the 19 month and 49 month evaluations after the cessation of the speech therapy. Provides support for ongoing speech and language services as well as comprehensive neuropsychological rehabilitation services for a longer duration than 6-12 months after a brain insult.
- Practical considerations: Administration of the full battery would be helpful so as to have full indicies with which to evaluate rate of change in an individual

DOMAIN: MEMORY

Wechsler Memory Scale-III (WMS-III)

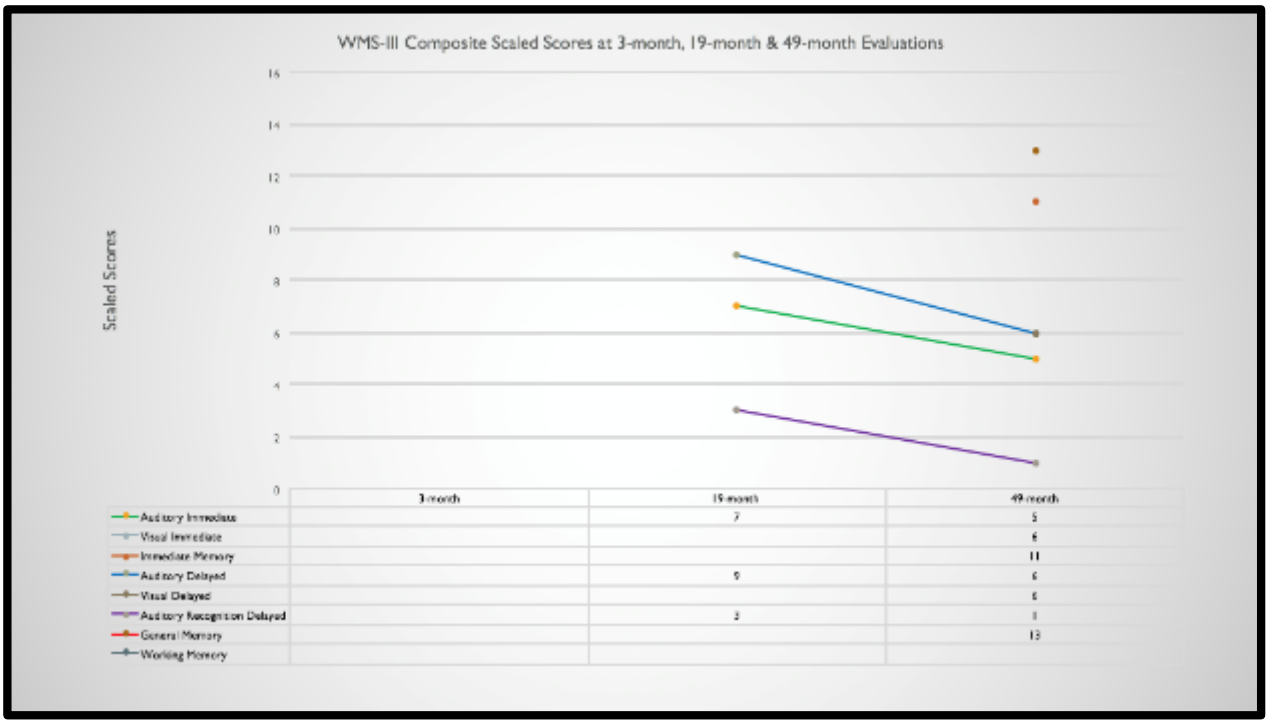
Rivermead Behavioural Memory Test (RBMT)

Fuld Object Memory Exam (FOME)

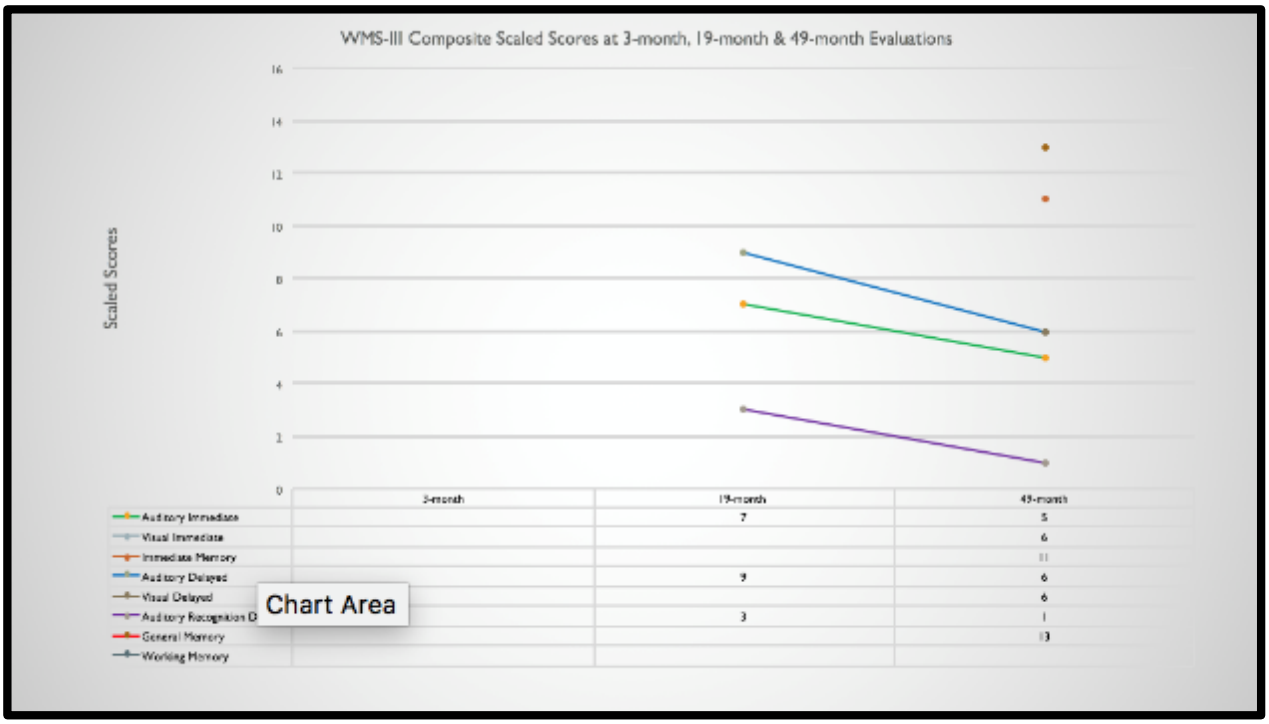
Test of Memory and Malingering (TOMM)

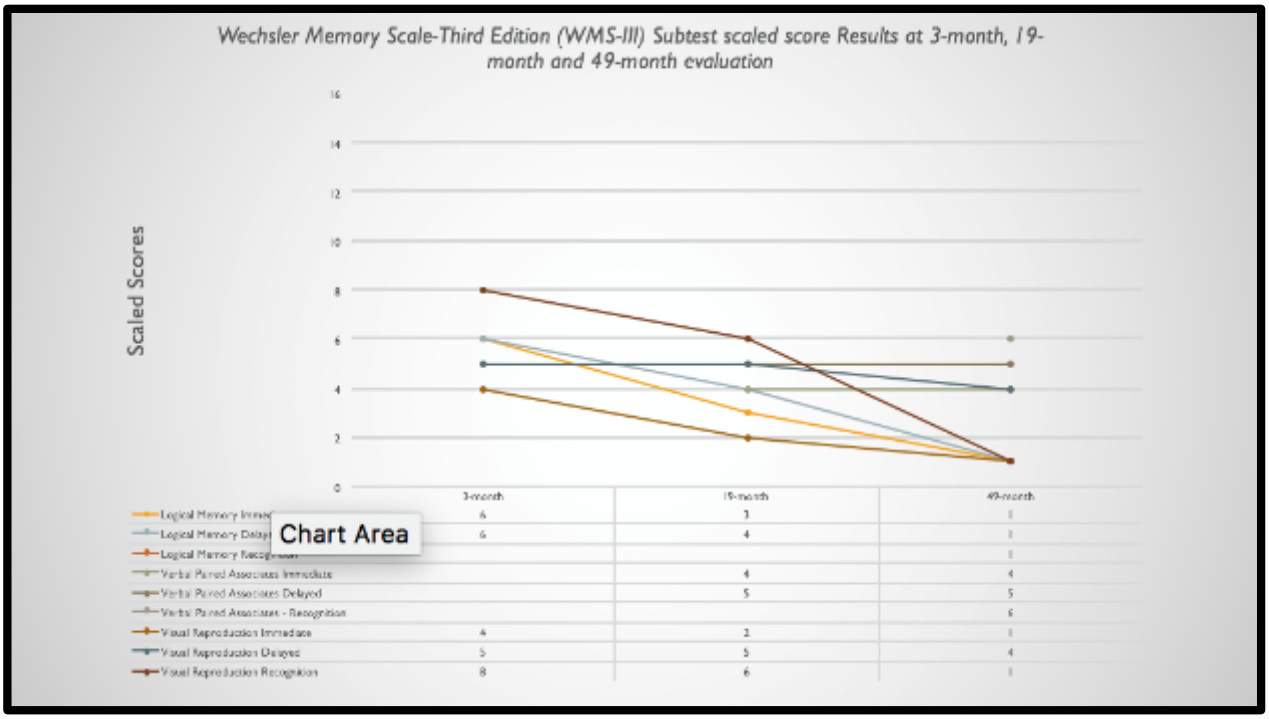
Wechsler Memory Scale-Third Edition (WMS-III) Composite Scaled Score Results at 3, 19 and 49-month evaluation

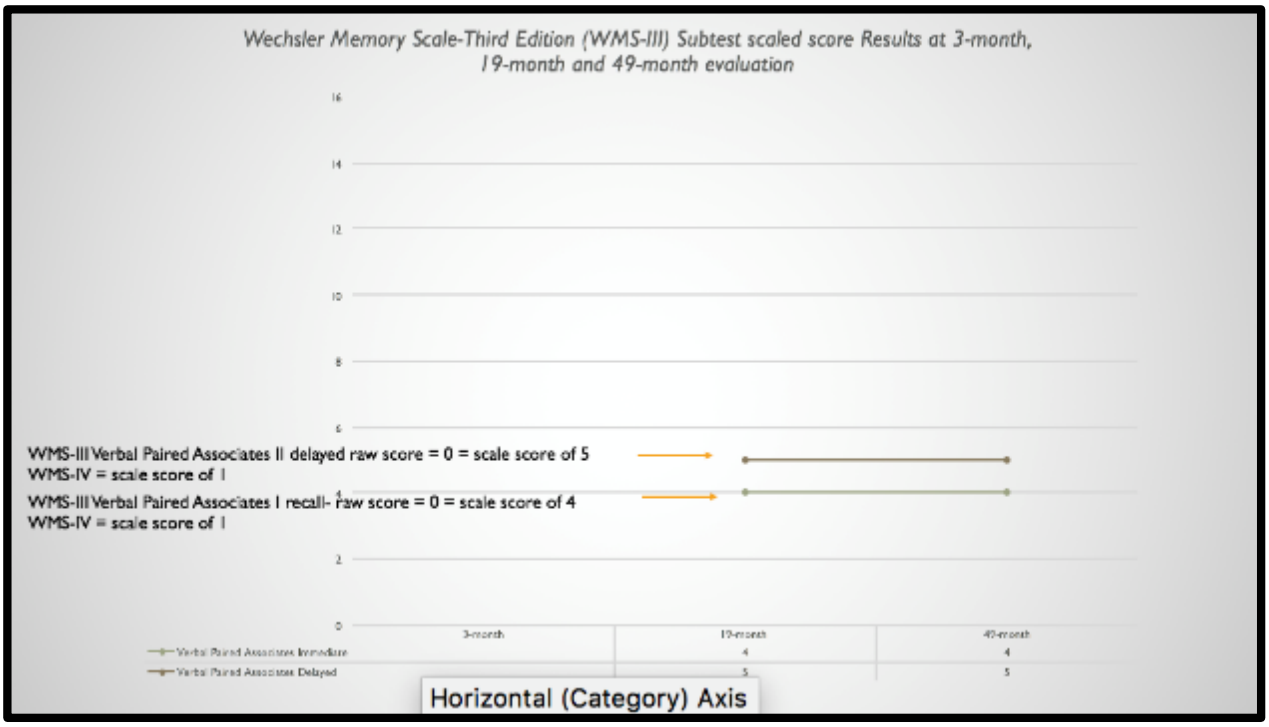
Subtests	3-month	19-month	49-month
Auditory Immediate	* --	7	5
Auditory Delayed	* --	9	6
Auditory Recognition Delayed	* --	3	1
Visual Immediate	* --	* --	6
Visual Delayed	* --	* --	6
Immediate Memory	* --	* --	11
General Memory	* --	* --	13
Working Memory	* --	* --	* --


WMS-III Composite Scaled Scores at 3-month, 19-month & 49-month Evaluations
Scaled Scores
16
14
12
10
8
6
4
2
0
3-month
19-month
49-month
Auditory Immediate
7
5
Visual Immediate
6
Immediate Memory
11
Auditory Delayed
9
6
Visual Delayed
6
Auditory Recognition Delayed
3
1
General Memory
13
Working Memory


WMS-III Composite Scaled Scores at 3-month, 19-month & 49-month Evaluations
Scaled Scores
16
14
12
10
8
6
4
2
0
3-month
19-month
49-month
Visual Immediate
6
Immediate Memory
11
Visual Delayed
6
General Memory
13
Working Memory

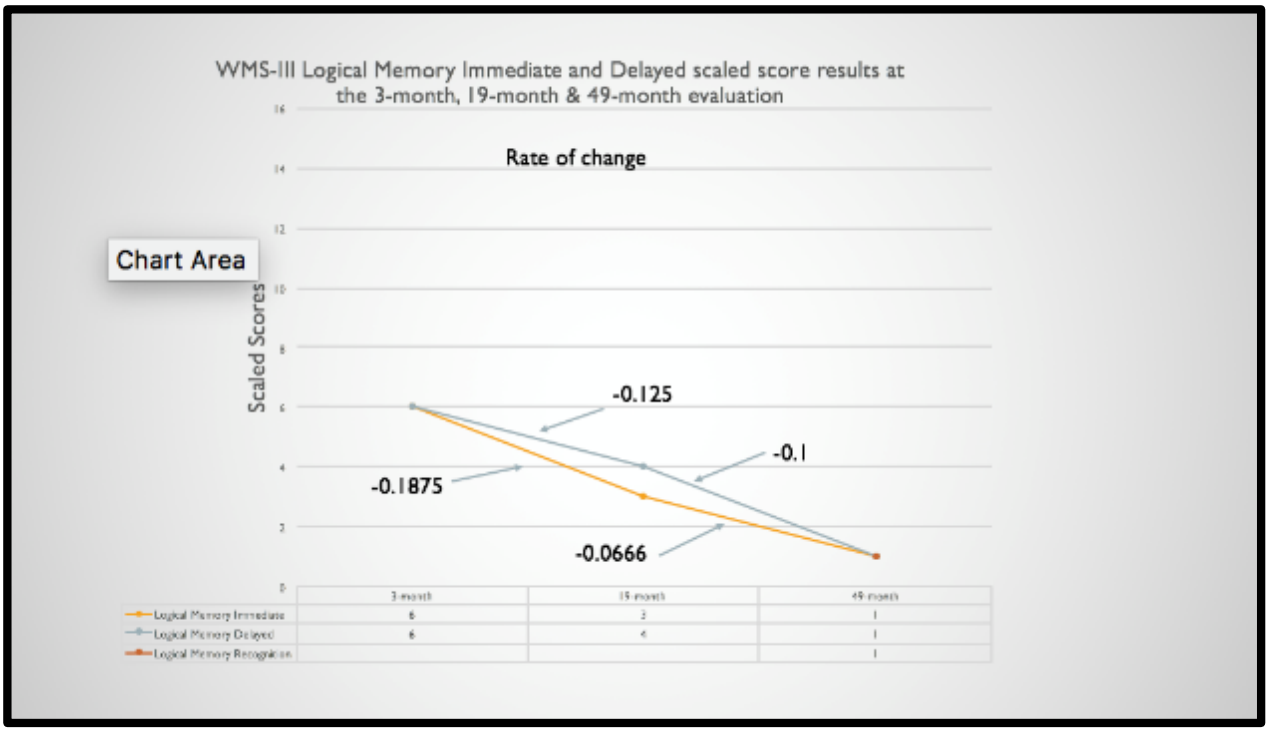

WMS-III Composite Scaled Scores at 3-month, 19-month & 49-month Evaluations
Scaled Scores
16
14
12
10
8
6
4
2
0
3-month
19-month
49-month
Auditory Immediate
Visual Immediate
Immediate Memory
Auditory Delayed
Visual Delayed
Auditory Recognition D
General Memory
Working Memory
7
5
6
11
9
6
6
3
1
13
Chart Area


Wechsler Memory Scale-Third Edition (WMS-III) Subtest scaled score Results at 3-month, 19-month and 49-month evaluation
Scaled Scores
16
14
12
10
8
6
4
2
0
3-month
19-month
49-month
Logical Memory Immed
Logical Memory Delay
Logical Memory Recogn
Verbal Paired Associates Immediate
Verbal Paired Associates Delayed
Verbal Paired Associates - Recognition
Visual Reproduction Immediate
Visual Reproduction Delayed
Visual Reproduction Recognition
6
6
4
5
4
5
3
4
8
3
4
6
2
5
6
4
1
1
1
4
5
6
1
4
1
Chart Area



WMS-III Logical Memory

Subtests	3-month	19-month	49-month
Logical Memory Immediate	6	3	1
Logical Memory Delayed	6	4	1
Logical Memory Recognition			1



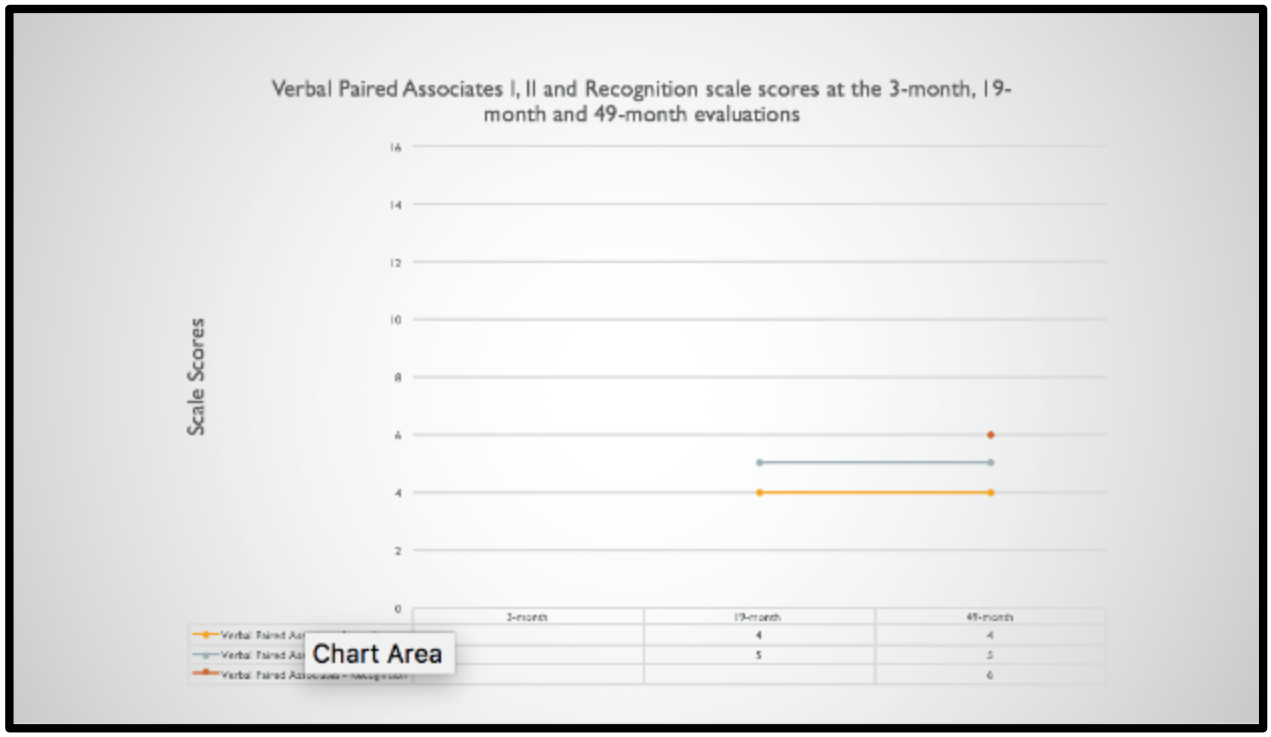
Subtests	3-month	19-month	49-month
Logical Memory Immediate	6	3	1
Logical Memory Delayed	6	4	1
Logical Memory Recognition			1

3-month versus the 19-month evaluation – paired-samples *T*-test = significant difference between the scores for 3-month (M=6, SD=0) and 19-month (M=3.5, SD=0.707) conditions; t(2)=5.000, p = 0.038

19-month versus the 49-month evaluation – paired-samples *T*-test = significant difference between the scores for 19-month (M=3.5, SD=0.707) and 49-month (M=1, SD=0) conditions; t(2)=5.000, p = 0.038.

Verbal Paired Associates

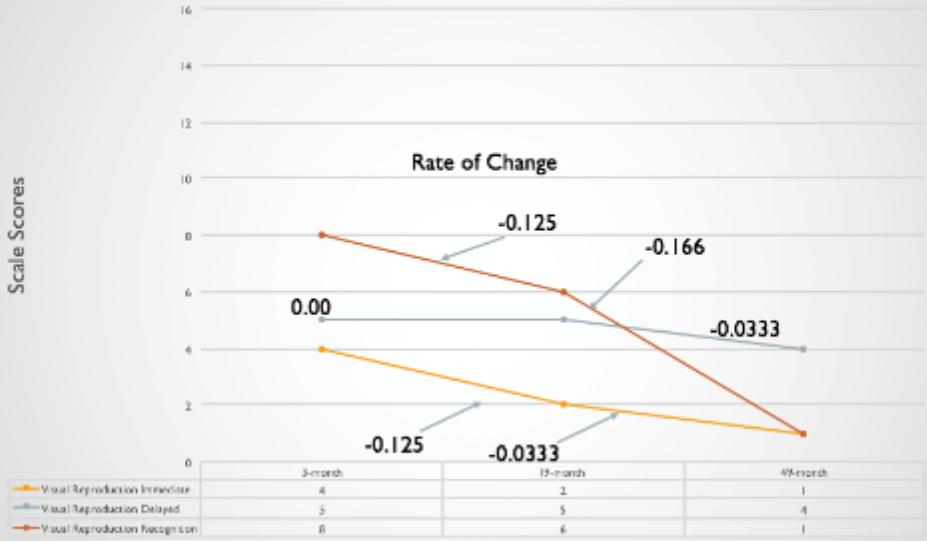
Subtests	3-month	19-month	49-month
Verbal Paired Associates Immediate	Overwhelmed-administration discontinued	4	4
Verbal Paired Associates Delayed	N/A	5	5
Verbal Paired Associates - Recognition	N/A	not administered	6



WMS-III Visual Reproduction- Immediate, Delayed and Recognition

Subtests	3-month	19-month	49-month
Visual Reproduction Immediate	4	2	1
Visual Reproduction Delayed	5	5	4
Visual Reproduction Recognition	8	6	1

Visual Reproduction Immediate, Delayed and Recognition at 3-month, 19-month and 49-month evaluations



No significant difference 3-month (M=5.66, SD=2.080) and 19-month (M=4.33, SD=2.080); t(4)=0.784, p = 0.477 or 19-month(M=4.33, SD=4.2.080) and 49-month (M=2, SD=1.732) conditions; t(4)=1.492, p = 0.210.

WMS-III Subtest average monthly changes in scale scores between 3-month and 19-month evaluation and 19-month and 49-month evaluation

Subtests	Change in scaled scores per month between 3-month and 19-month evaluations	Change in scaled scores between 19-month and 49-month evaluations
Logical Memory Immediate	-0.1875	-0.0666
Logical Memory Delayed	-0.125	-0.1
Logical Memory Recognition	* --	* --
Verbal Paired Associates Immediate	* --	0.00
Verbal Paired Associates Delayed	* --	0.00
Verbal Paired Associates - Recognition	* --	* --
Visual Reproduction Immediate	-0.125	-0.0333
Visual Reproduction Delayed	0	-0.0333
Visual Reproduction Recognition	-0.125	-0.1666
	Red = Larger Rate of Change	

Standard Profile Scoring for the Rivermead Behavioral Memory Test

Items	2 points	1 point	0 points
1st and 2nd Name	4	3	0-2
Belonging	4	3	0-2
Appointment	2	1	0
Pictures	10	9	0-8
Immediate route	5	4	0-3
Delayed route	5	4	0-3
Message	6	5	0-4
Orientation	9	8	0-7
Date	1	1 day out	2 or more days out
Faces	5	4	0-3
Immediate story	6 or more	4-5.5	3.5 or less
Delayed story	4 or more	2-3.5	1.5 or less

Performed at 8 month and 49 month evaluation

1) Immediate Story Recall (Total out of 21)
2) Delayed Story Recall (Total out of 21)
3) Immediate Route Recall (Total out of 5)
4) Delayed Route Recall (Total out of 5)
5) 20 minute Predetermined Task (completed with or without cueing)
6) 20 minute Personal Belongings (completed with or without cueing)
7) Name (completed with or without cueing

Total Points Possible on overall test is 12

Rivermead Behavioral Memory Test- Results

	8-month	49-month
Overall Score	2	0
Immediate Story Recall	0	0
Delayed Story Recall	0	0
Immediate Route Recall	0	0
Delayed Route Recall	0	0
20 min predetermined task	Not able to complete	Not able to complete
20 min personal belongings	Yes with prompt	Not able to complete
Name	Unable to recall with cueing	Unable to recall with cueing

Rivermead Behavioral Memory Test- Results

	8-month	49-month
Overall Score (out of 12)	2	0
Immediate Story Recall	0 (3 of 21)	0 (0 of 21)
Delayed Story Recall	0 (0 of 21)	0 (0 of 21)
Immediate Route Recall	0 (1 of 5)	0 (0 of 5)
Delayed Route Recall	0 (0 of 5)	0 (0 of 5)
20 min predetermined task	Not able to complete	Not able to complete
20 min personal belongings	Yes with prompt	Not able to complete
Name	Unable to recall with cueing	Unable to recall with cueing

Fuld Object Memory Test II Interference Results at 19-month evaluation

Subtests	**Scores**
Storage	38
Retrieval	22
Repeated Retrieval	10
Ineffective Reminder	14
Delay Recall	5
Recognition	5
Total	10

Test of Memory and Malingering Results at 3-month & 19-month Evaluation

	3-month	19-month
Trial 1	46	42
Trial 2	50	49
Retention	48	50

DOMAIN: EXECUTIVE FUNCTIONING

Delis-Kaplan Executive Function System Color Word Interference (D-KEFS C/W Interference)

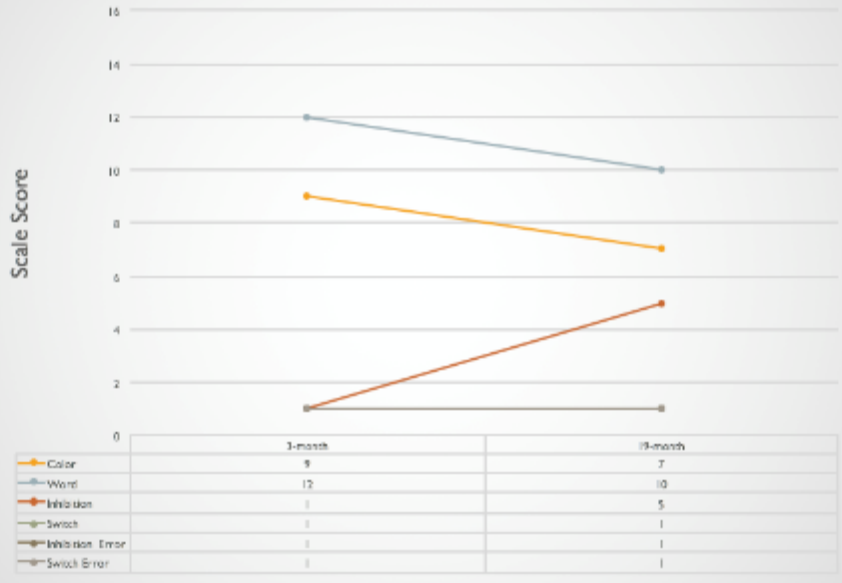
Wisconsin Card Sorting Test (WCST)

Behavioral Assessment of Dysexecutive Syndrome (BADS)

D-KEFS C/W Interference Scale Score Results at 3-month & 19-month Evaluation

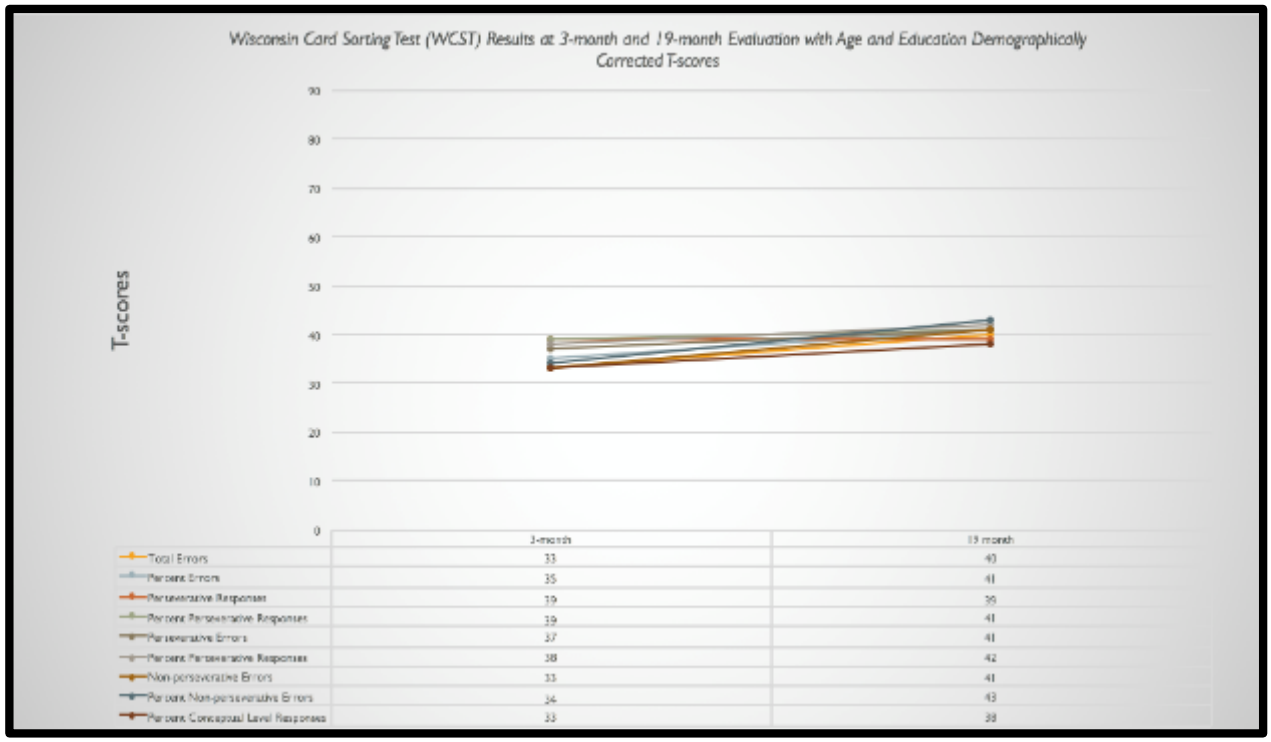
Subtests	3-month	19-month
Color	9	7
Word	12	10
Inhibition	1	5
Switch	1	1
Inhibition Error	1	1
Switch Error	1	1

D-KEFS C/W Interference Scale Score Results at 3-month & 19-month Evaluation



Wisconsin Card Sorting Test (WCST) Results at 3-month and 19-month Evaluation with Age and Education Demographically Corrected T-scores

	3-month T-scores	19-month T-scores
Trials Administered	* ..	* ..
Total Correct	* ..	* ..
Categories Completed	* ..	* ..
Trials to Complete 1st Category	* ..	* ..
Total Errors	33	40
Percent Errors	35	41
Perseverative Responses	39	39
Percent Perseverative Responses	39	41
Perseverative Errors	37	41
Percent Perseverative Responses	38	42
Non-perseverative Errors	33	41
Percent Non-perseverative Errors	34	43
Conceptual Level Responses	* ..	* ..
Percent Conceptual Level Responses	33	38
Categories Completed	* ..	* ..
Learning to Learn	* ..	* ..



A paired-samples T-test assuming was conducted on the available categories of the WCST and there was a significant difference at the p<0.001between the scores for the 3-month (M=35.66, SD=2.598) and 19-month (M=40.66, SD=1.5) and condition; t(16)=- -5.000, p = 0.000.

BADS consists of six subtests with the associated areas of EF evaluation as follows:

1) Rule Shift Cards tests inhibitory control and ability to switch focus.
2) Action Program tests the ability for the patient to approach a problem and develop an effective solution that is congruent with the perimeters of the exercise.
3) Key Search tests the ability to formulate an effective strategy using implicit situational information.
4) Temporal Judgment involves evaluating abstract judgment and thinking regarding four common events.
5) Zoo Map tests formulation and execution of a plan limited by certain rules.
6) Six Elements tests the patient's ability to plan and organize the task and then manage the construct of time.
7) BADS Dysexecutive Questionnaire (DEX) that is distributed to the patient and caregivers for self-rating. It consists of 20 questions regarding patient effectiveness with daily living. There is a maximum score of 80 points on each questionnaire.

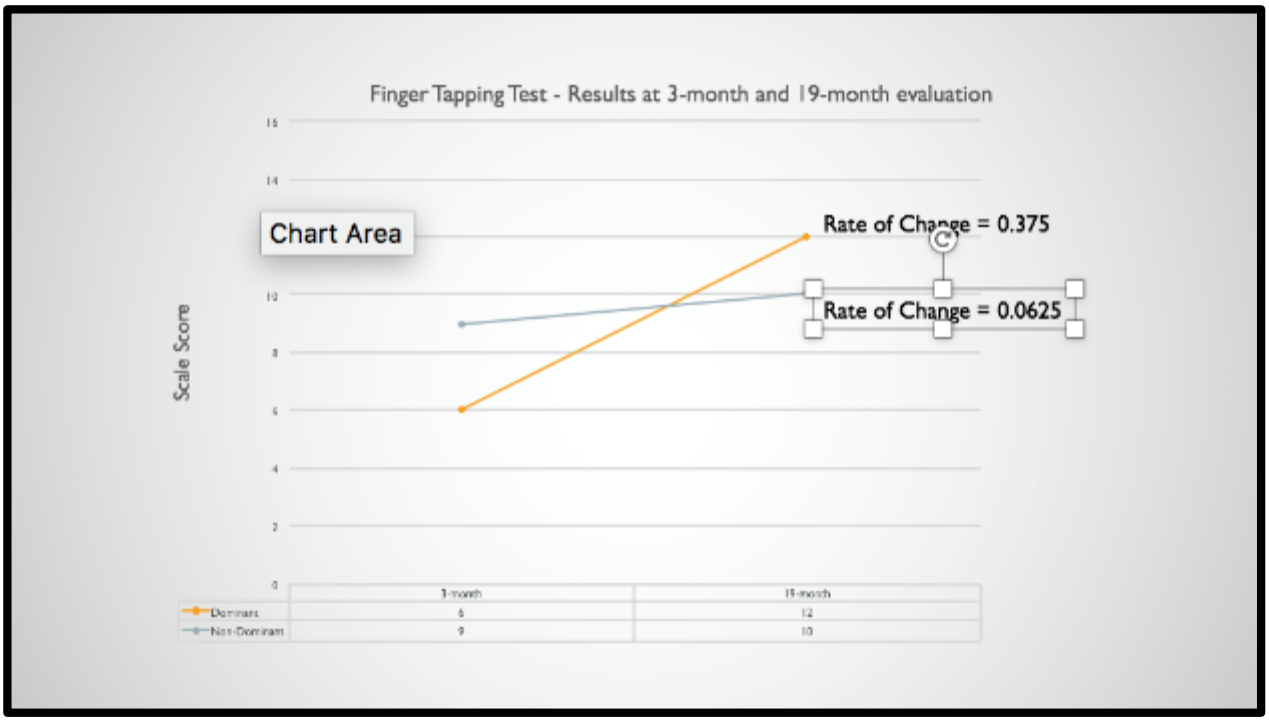
Behavioral Assessment of the Dysexecutive Syndrome (BADS) scores on the 49-month evaluation

Category	49-month
Profile Total	0
Action Program	0
Key Search	0
Modified Six Elements	Not able to complete
Rule Shift Cards	-1
Zoo Map	0
Temporal Judgment	1

The patient had more than 20 total errors on the Rule Shift cards leading to a profile score of zero. He took much longer than 67 seconds to complete the test and, according to the standardization for the test, that leads to the subtraction of 1 from the profile score, leaving the patient with a profile score of negative one (-1). His overall score was 0 which places him in the "profoundly impaired" category.

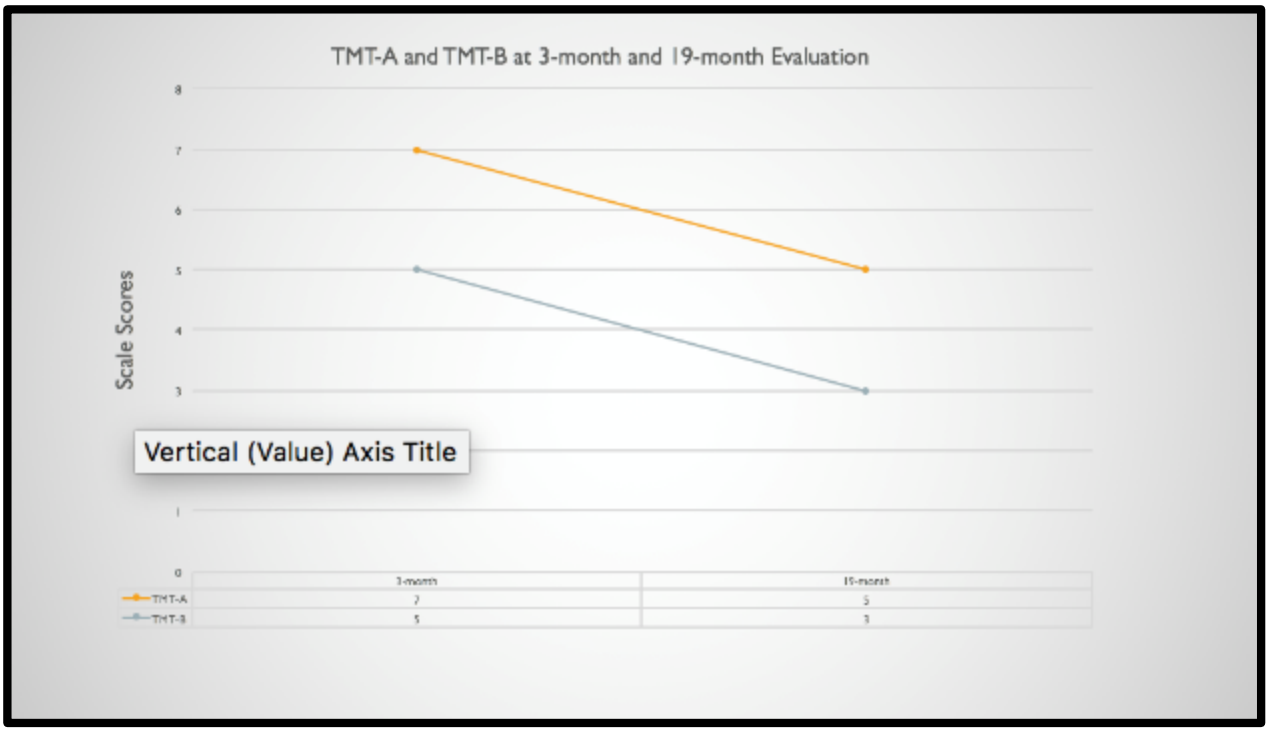
Finger Tapping Test at 3-month and 19-month evaluations

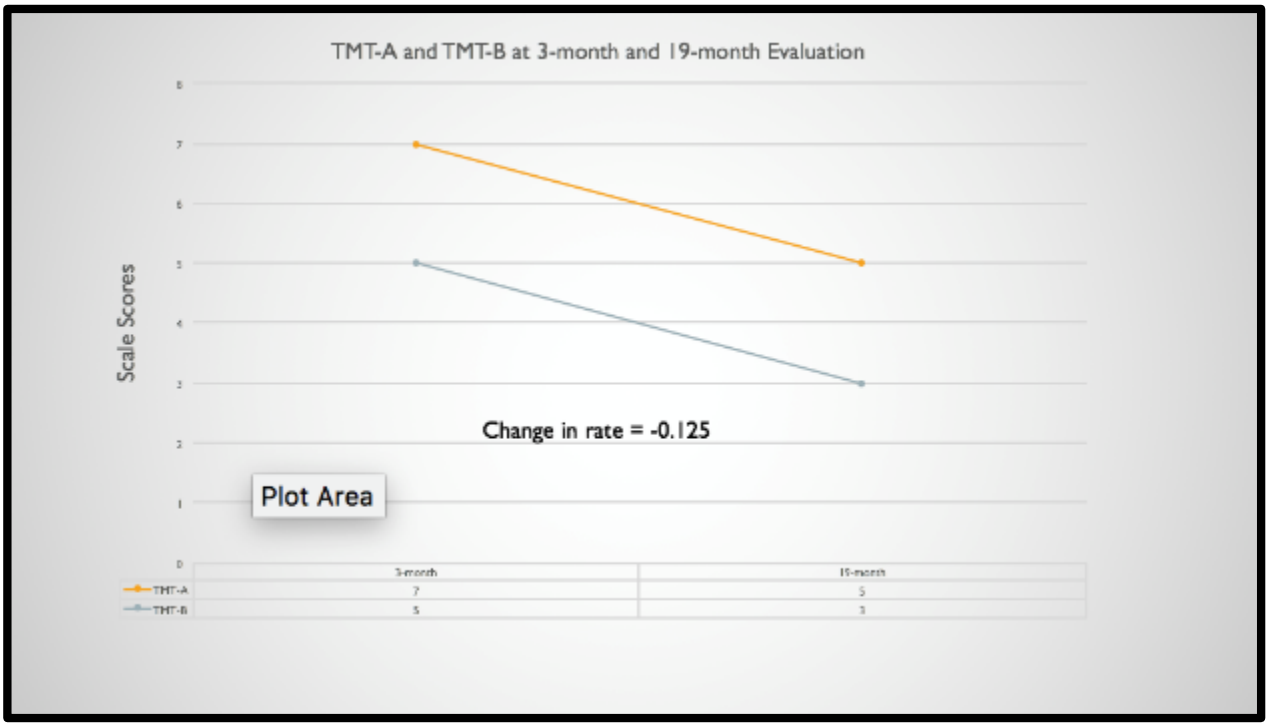
	3-month	Descriptive Classification	19-month	Descriptive Classification
Dominant	6	Mildly Impaired	12	Average
Non-Dominant	9	Average	10	Average



Trail Making Test Part A & B results at the 3-month and 19-month evaluation

	3-month	Descriptive Classification	19-month	Descriptive Classification
TMT-A	7	Average	5	Low
TMT-B	5	Low	3	Very Low


TMT-A and TMT-B at 3-month and 19-month Evaluation
Scale Scores
Vertical (Value) Axis Title
3-month
19-month
TMT-A
7
5
TMT-B
5
3


TMT-A and TMT-B at 3-month and 19-month Evaluation
Scale Scores
Change in rate = -0.125
Plot Area
3-month
19-month
TMT-A
7
5
TMT-B
5
3

DOMAIN: LANGUAGE

The Controlled Oral Word Association Test (COWAT)

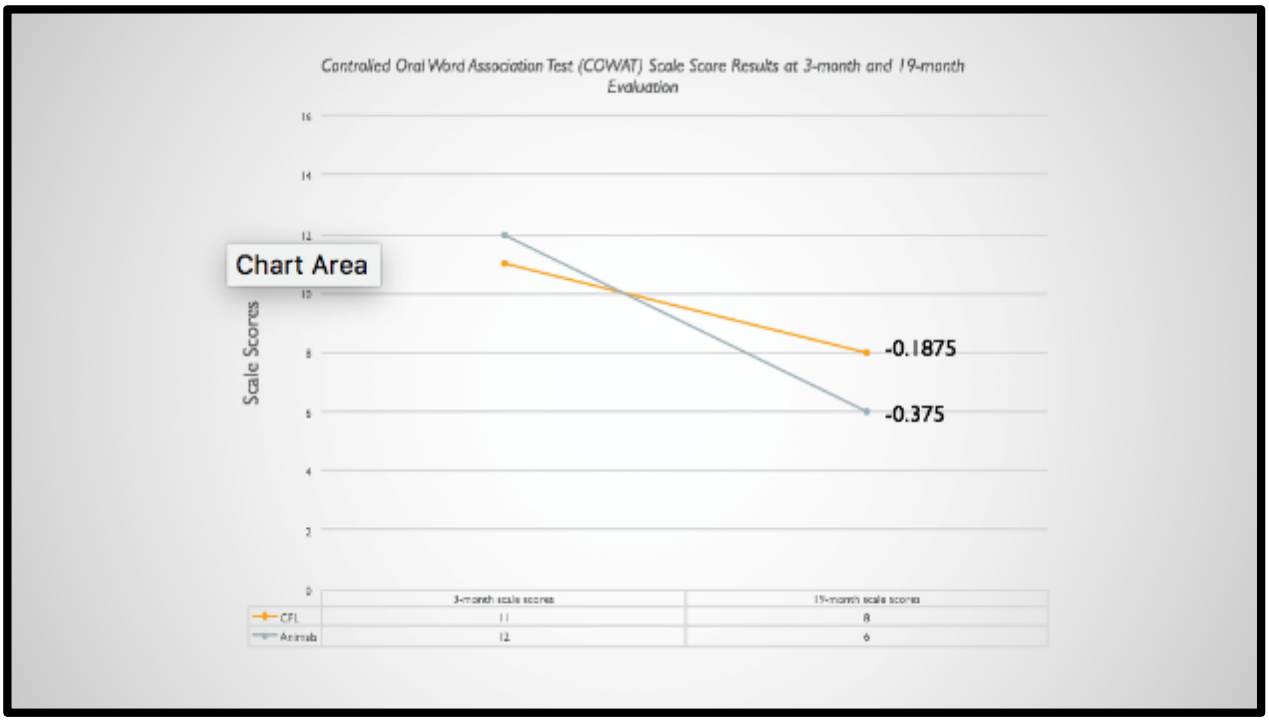
Wide Range Achievement Test

Boston Diagnostic Aphasia Examination (BDAE).

Boston Naming Test - Second Edition

Controlled Oral Word Association Test (COWAT) Scale Score Results at 3-month and 19-month Evaluation

Subtests	3-month Scale Scores	19-month Scale Scores
CFL	11	8
Animals	12	6



Controlled Oral Word Association Test (COWAT) Scale Score Results at 3-month and 19-month Evaluation

Subtests	3-month Scale Scores	19-month Scale Scores
CFL	11	8
Animals	12	6

There was a significant difference between the scores for 3-month (M=77.5, SD=40.5) and the 19-month (M=18.5, SD=144.5) conditions; $t(2)=6.135$, $p = 0.026$.

Wide Range Achievement Test (WRAT) Tan Form Results at 19-Month Evaluation

Subtests	Standard Scores	Percentile	Grade Equivalent
Reading	115	84	PHS
Spelling	110	75	PHS
Arithmetic	93	32	5

Boston Diagnostic Aphasia Examination 3rd Edition at 3-month and 19-month

	3-month	19-month
Raw	12	8
Errors	0	4
Inference	1	0
Percentile		< 1

Given that there are many subtests in the BDAE, and the chart did not specify which subtests were administered, it is impossible to know from where the raw scores were derived. The chart does note that, at the 19-month evaluation, the patient's BDAE score was ranked at the less than one percent range. Although it was not stated, it can be assumed that his percentile rank at the 3-month evaluation was slightly higher.

Boston Naming Test, 2nd Edition results at the 3-month and 19-month evaluation

	3-month	19-month
T scores	49	42
Descriptive Classification	Average	Low average
Percentile	47%	21%

DOMAIN: VISUAL SPATIAL

Rey-Osterrieth Complex Figure test (ROCF).

The Rey-Osterrieth Complex Figure Test results at the 3-month and 19-month evaluations

	3-month	19-month
Copy	90%	90%
30-min copy	11%	11%
Approximate scale score	6	6

DOMAIN: PERSONALITY

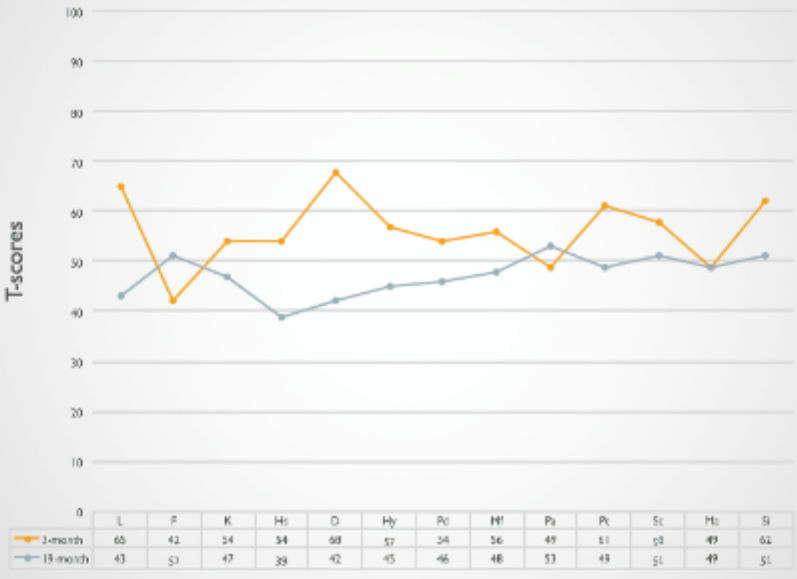
Minnesota Multiphasic Personality Inventory-2.

The Scales of Independent Behavior Revised.

Minnesota Multiphasic Personality Inventory-2 (MMPI-2) T-score Results at 3-month and 19-Month Evaluation

Scales	3-month	19-month
L (Lie)	65	43
F (Infrequency)	42	51
K (Correction)	54	47
Hs (Hysteria)	54	39
D (Depression)	68	42
Hy (Hysteria)	57	45
Pd (Psychopathic Deviate	54	46
Mf (Masculinity-Femininity)	56	48
Pa (Paranoia)	49	53
Pt (Psychasthenia)	61	49
Sc (Schizophrenia)	58	51
Ma (Hypomania)	49	49
Si (Social Introversion)	62	51

Minnesota Multiphasic Personality Inventory-2 (MMPI-2) T-score Results at 3-month and 19-Month Evaluation



Minnesota Multiphasic Personality Inventory-2 (MMPI-2) T-score Results at 3-month and 19-Month Evaluation

A paired-samples *t*-test assuming equal variances was conducted to compare the MMPI-2 and there was a significant difference between the scores for 3-month (M=56.07, SD=7.05) and the 19-month (M=47.23, SD=4.106) conditions; $t(24)=3.908$, $p = 0.001$

Scales of Independent Behavior-Revised (SIB-R) Domain Percentiles at 49-Month Assessment

	%iles
Motor Skills	98
Social Interaction and Communication Skills	1
Personal Living Skills	96
Community Living Skills	3
Broad Independence (Full Scale)	<0.1

INTERVENTIONS

The patient's available medical records contain little information on interventions. For the 3-month evaluation, there are indications that, it was recommended that he would benefit from individual and group neurorehabilitation along with referrals for speech therapy and vocational assistance. According to the medical records, this individual did engage in the neurorehabilitation process and saw improvement, but medical records indicate that the rehabilitation process was discontinued within a short time frame.

DISCUSSION

	3 month-19 month	19-month-49-month
WAIS-III VIQ-PIQ	N/A	$p = 0.032.$
WAIS-III VCI-POI	$P = 0.036.$	$P = 0.016$
WAIS-III Subtests excluding LNS and OA	$p = 0.041$	$p = 0.01.$
WMS-III - Logical Memory Immediate and Delayed	$p = 0.038$	$p = 0.038$
WCST	$p = 0.000.$	N/A
COWAT	$p = 0.026.$	N/A
MMPI	$p = 0.001$	N/A

ASSESSMENTS ADMINISTERED

Assessment Instruments	3-month	8-month	19-month	49-month
Behavioural Assessment of Dysexecutive Syndrome (BADS)				x
Boston Diagnostic Aphasia Examination- Third Edition (BDAE-3)	x		x	
Boston Naming Test (BNT)	x		x	
Controlled Oral Word Association Test (COWAT)	x		x	
Delis-Kaplan Executive Function System- Color/Word Interference (DKEFS-C/W)	x		x	
Finger Tapping Test (FTT)	x		x	
Fuld Object Memory Evaluation (FOME			x	
Minnesota Multiphasic Personality Inventory – Second Edition (MMPI-2)	x		x	
Rey Osterrieth Complex Figure (ROCF) and 30-minute delay	x		x	
Rivermead Behavioural Memory Test (RBMT)		x		x
Scales of Independent Behavior- Revised (SIB-R)				x
Test of Memory Malingering (TOMM)	x		x	
Trail Making Test Part A and B (TMT-A, TMT-B)	x		x	
Wechsler Adult Intelligence Scale- Third Edition (WAIS-III)	x		x	x
Wechsler Memory Scale- Third Edition (WMS-III)	x		x	x
Wide Range Achievement Test (WRAT)			x	
Wisconsin Card Sorting Test (WCST)	x		x	

Yellow indicates tests where there was a significant difference of $p<0.05$.

Implications and areas for future research

The investigation led to important considerations:

- Vulnerability of geriatric individuals to substantial brain injury at lower mechanism threshold for force..
- Reconsideration for concussion and appropriate interventions. Orientation level may not be sufficient
- Residual and potentially layering effect of the inflammatory process that may accentuate a dementia process
- Genetic biomarker analysis in neuropsychology can be used to provide more data
- Prolonged neurocognitive rehabilitation and prevention interventions for individuals.
- Use of longitudinal neuropsychological reassessments
- Use of rates of change in test scores to delineate neuropathological processes.
- Development of assessments which can be re-administered every 3-6 months for monitoring.
- Consolidated data system for providers to allow for data collection and analysis.